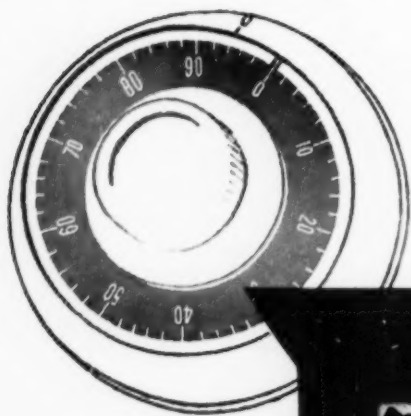


**MAY 1953**

# **Chemical Engineering Progress**

**PUBLISHED MONTHLY BY THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS**

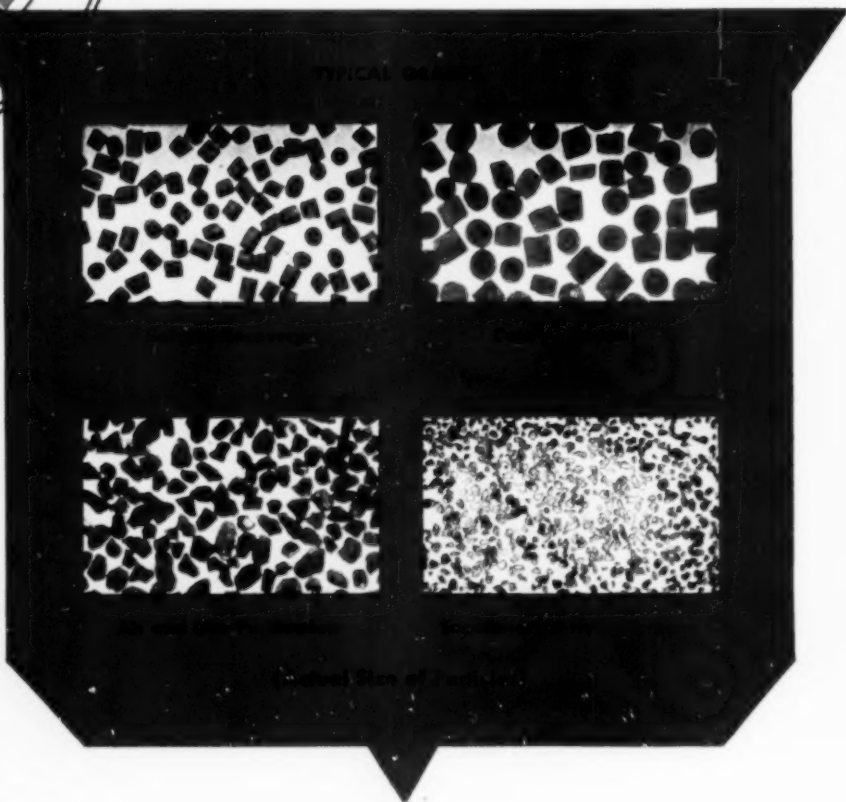
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# Chemical Engineering Progress

MAY, 1953

Volume 49, No. 5

Editor: F. J. Van Antwerpen

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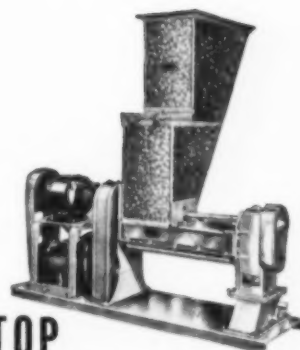
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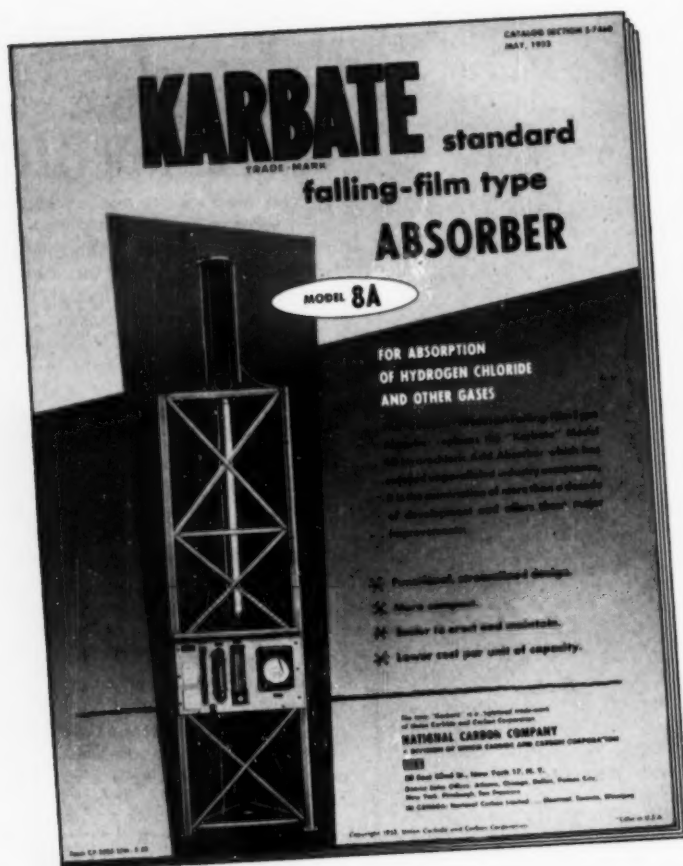
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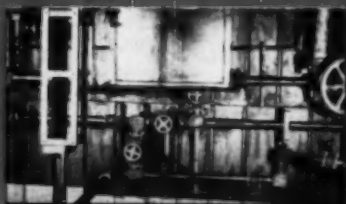
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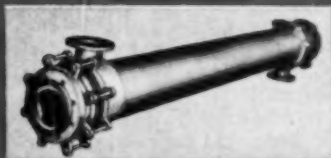
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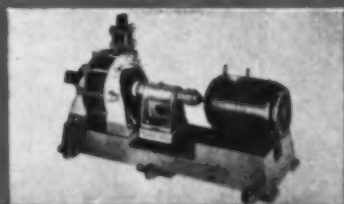
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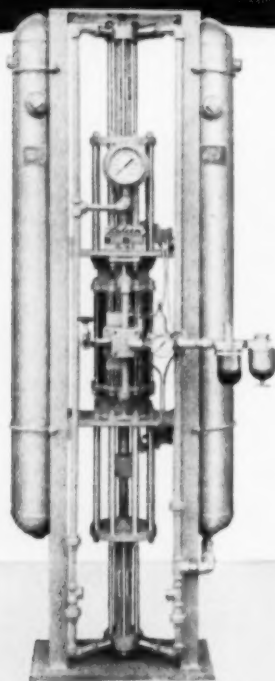
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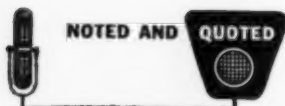
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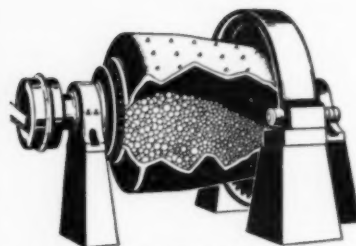
—Contributions of Engineering  
to the Plastics Industry  
Frank C. McGrew

### Industry and the Atom

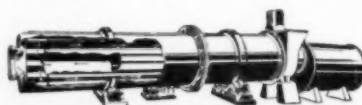
There are two limits that prudent judgment would set to the level of research effort. . . . One is a money limit. How large a part of our national income can we afford to spend on research in the field of atomic energy however unknown and important it may be? . . .

The other ceiling on proper expenditure for research in atomic energy is men. We should not support research by men who are too stupid or too badly trained to do effective work. We should not absorb all good men into the A.E.C. program leaving none for other research work or for teaching. Up until two or three years ago, I would have said that we were approaching that extreme. . . . Since that time . . . the postwar crop of young scientists has begun to swell the ranks of qualified men. I doubt that our research budgets have increased sufficiently to take care of rising costs and to make full use of this new talent—such use as we must make if we are to hold our leading position in the field of atomic energy. Remember that we can no longer depend on Western Europe for the basic discoveries as we have so largely in the past. In the present state

(Turn to page 8)



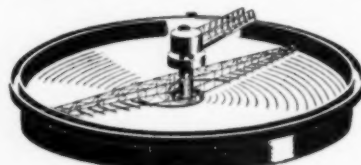
CONICAL & TRICONE MILLS



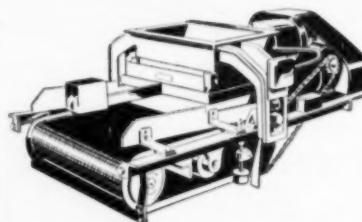
ROTARY DRYERS, KILNS, COOLERS



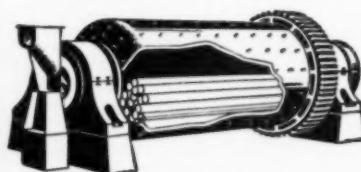
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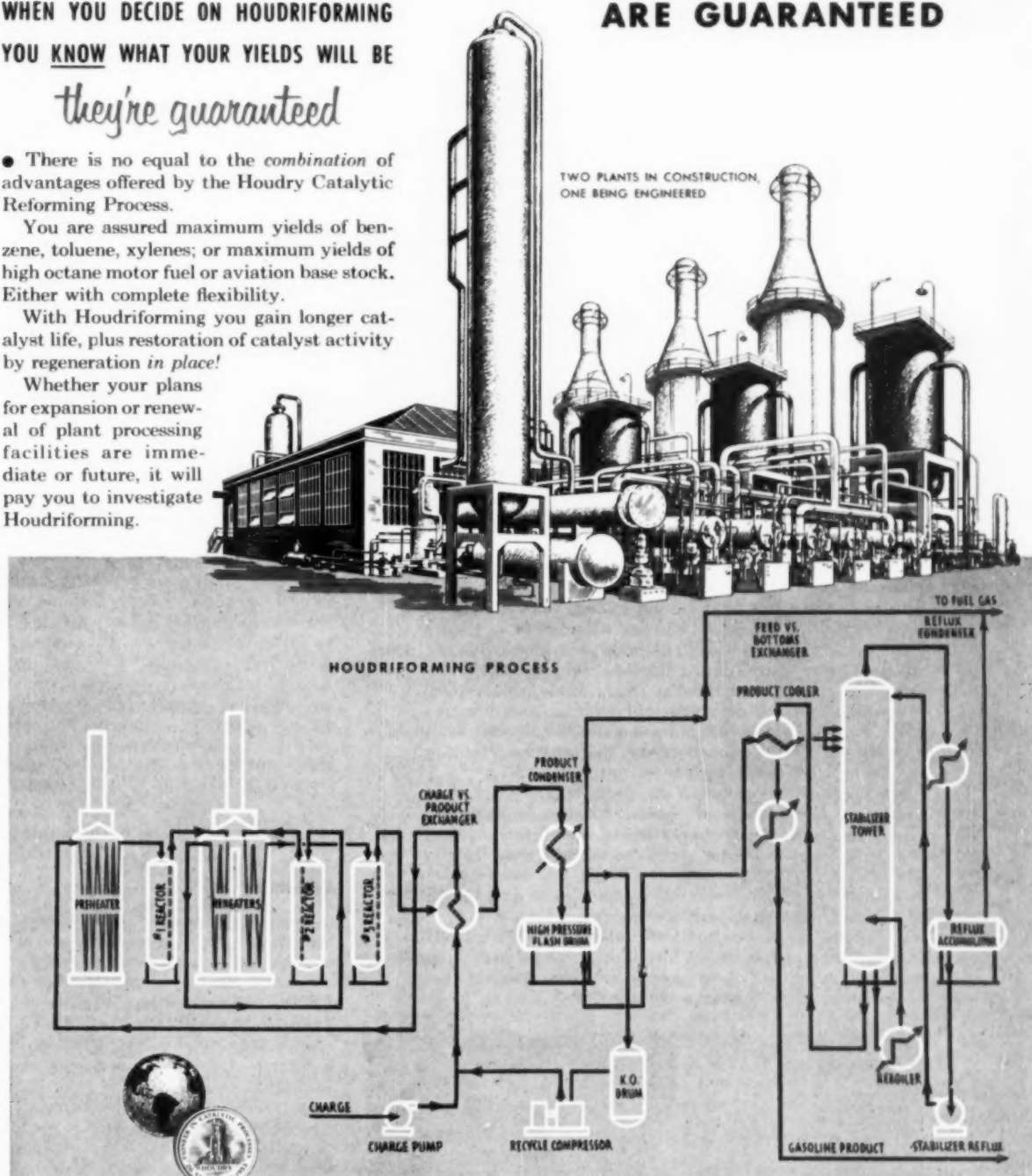
You are assured maximum yields of benzene, toluene, xylenes; or maximum yields of high octane motor fuel or aviation base stock. Either with complete flexibility.

With Houdriforming you gain longer catalyst life, plus restoration of catalyst activity by regeneration *in place*!

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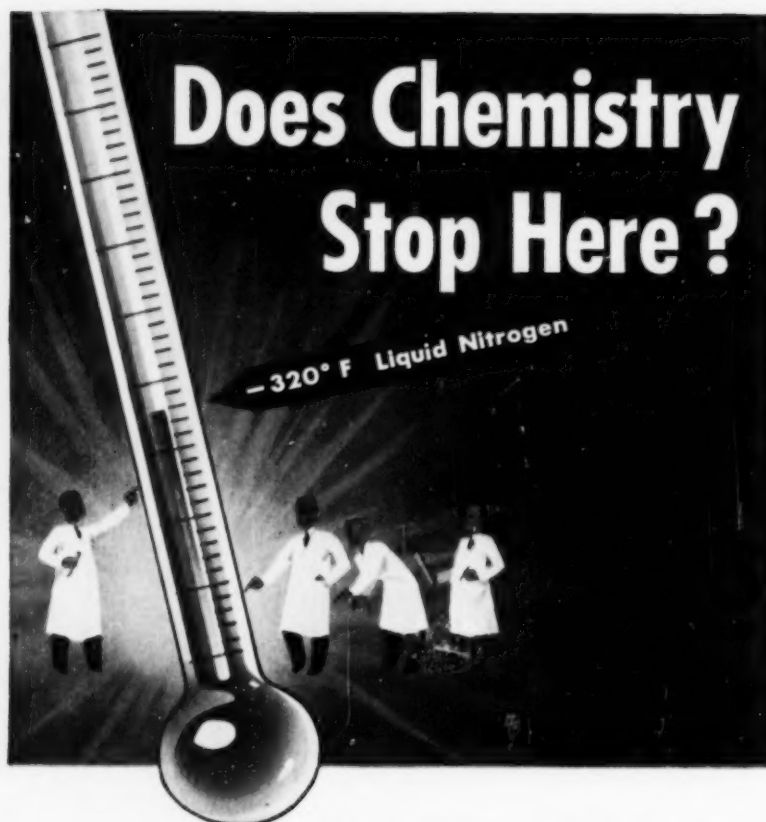
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At present, low-temperature chemistry is mostly an interesting combination of words. But this is changing. Chemicals which are extremely reactive at ambient temperature may conceivably be stabilized at low temperature. Knowledge of what happens at extreme low temperature can be of particular value to chemists as a key to the explanation of high-temperature reactions.

Today, facilities for extreme low temperature are part of a well-equipped laboratory for virtually all fields of research. Write for descriptions of low-temperature equipment and applications—Bulletin CEP 22-3.

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of the world we had better work at developing new ideas as well as at using new ideas developed elsewhere.

If there is work that needs to be done and men able to do it, there remains only the question of money. . . . The research I have been talking about is done in three kinds of institutions, universities, government laboratories, and industrial laboratories. All the work in the government laboratories, most of that in industrial laboratories, and a large part of that in universities is paid for by the Federal government. The evils of this Federal monopoly are sometimes exaggerated. The actual research work is done by universities or industries in government-owned laboratories which they operate or in their own laboratories. Our [A.E.C.] plants are all operated by industrial companies. We obviously do make use of the talents of American industry and are even able to profit by the rivalry between the different companies operating our facilities. . . . But it would be healthier if the university work and industrial work were not so heavily subsidized. Universities are notoriously hard up at all times and particularly so in the present period of inflation. Industries are not philanthropic institutions and can hardly be expected to put millions into atomic energy research until the prospects of ultimate profit are better established. There are signs that industry may begin to invest substantially in the power-reactor field in the next few years. Although their efforts probably cannot entirely replace the efforts of the Atomic Energy Commission for some years, even in reactor development, we hope the possibility of profits will bring more competition and more rapid progress.

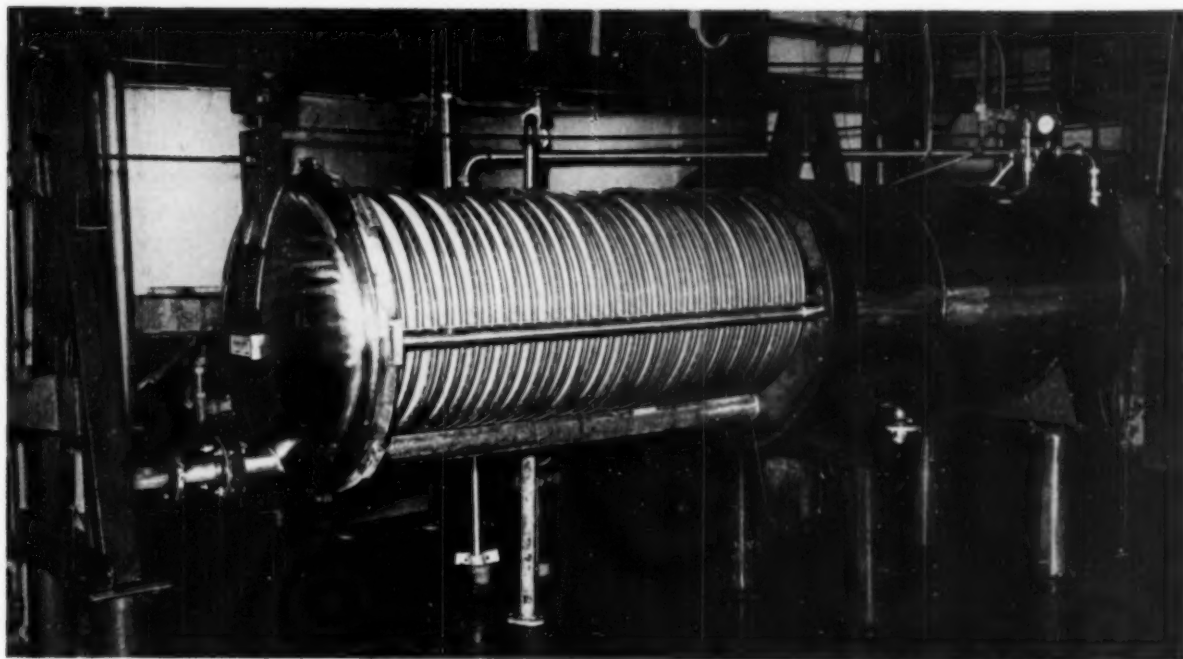
—Henry D. Smyth

United States Atomic Energy Commission

### Cheek by Jowl

Another characteristic of our times is the way in which organizations of various kinds—business, educational, governmental and so forth—play ball together. Anybody who imagines that businessmen and government officials are always at swords' points should go to a meeting of a scientific or professional association and see the man from Monsanto Chemical and the man from the Department of Agriculture hobnobbing about their joint specialty. Anybody who thinks that university professors are all cloistered creatures remote from business should ask a member of the National Retail Dry Goods Association about the reports on his industry assembled at the Harvard Business School, or look into the close tie-up between the

(Turn to page 14)



## Here's a **BIG** filter that costs less to operate

The Niagara Style "H" Filter will filter liquids to high clarity, at rates up to 30,000 GPH.

It also gives you easy recovery or disposal of as much as 150 cu. ft. of solids at a time.

Sizes range up to 1,500 square feet of working filter area in one compact, leakproof unit.

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Cake discharge is faster than anything you've ever seen in a filter this big. Cakes can be blown dry in the filter, are then dropped into a discharge hopper simply by rapping the all-metal leaves with a rubber mallet. That's all there is to it.

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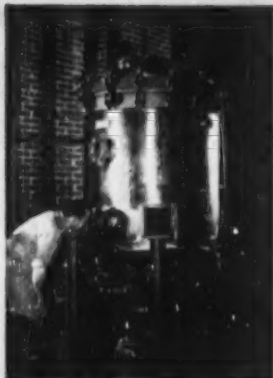
The simple fabricated shell can be constructed in stainless steel and special alloys for corrosion resistance, and can be readily and cheaply jacketed. Special construction, to match your needs, costs far less than usual for a filter of this size.

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How can we help you? We're equipped to test samples for filterability... pilot the filtration for you... design, build and install a filter or a complete system to fit your process.

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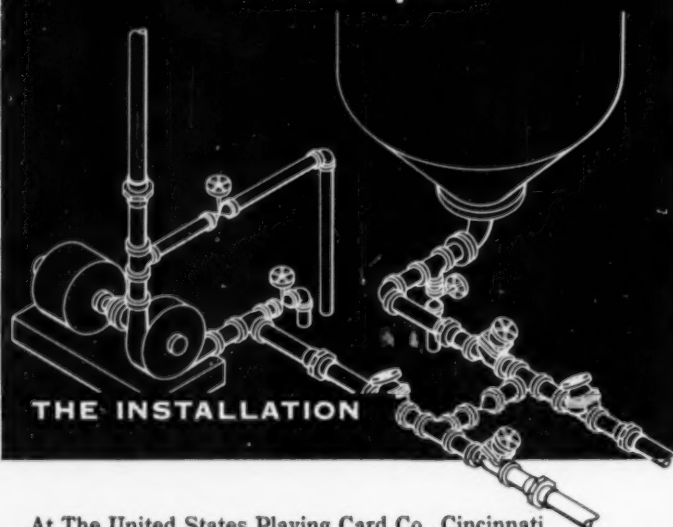
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# What a Difference in Valve Behavior ...on Heavy Coating Liquids for example



At The United States Playing Card Co., Cincinnati, using Crane Diaphragm Valves in handling paper coating "enamels" from storage tanks to pumps.

## THE CASE HISTORY

Previously, ground plug cocks and conventional gate valves were used. During normal shutdowns the heavy coating liquid would build up on seating surfaces, in stem threads and working parts. The cocks and gates would "freeze up"; were hard to operate, couldn't be shut tight. Recurring maintenance, cleaning, and replacements were a costly, annoying problem.

Switching to Crane Diaphragm Valves solved the problem. Their sealed-to-fluid bonnet and soft disc insert did the trick. None of the 48 Crane valves installed beginning more than 3 years ago, has needed service of any kind. They continue to operate freely and easily.

THE BETTER QUALITY...BIGGER VALUE LINE...IN BRASS, STEEL, IRON

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## VALVE SERVICE RATINGS

### SUITABILITY:

*None other like it*

### FEATURES:

*Fluid can't get into bonnet*

### MAINTENANCE COST:

*None*

### SERVICE LIFE:

*No sign of wear after 3 years*

### OPERATING RESULTS:

*Trouble and waste stopped*

### PRICE:

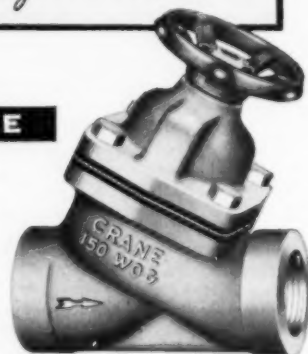
*O.K. — No premium*

### AVAILABILITY:

*Crane Catalog item - No. 1610*

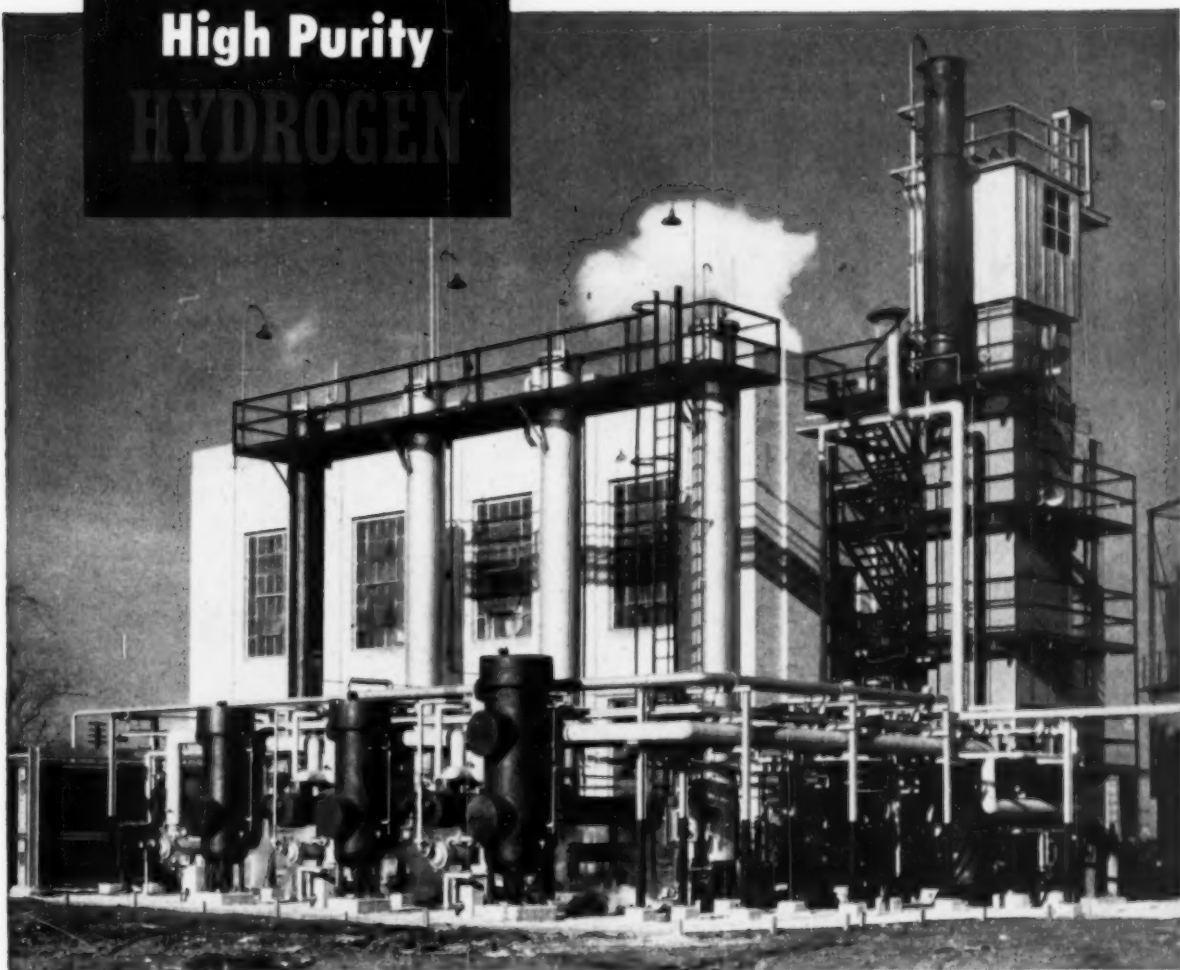
## THE VALVE

There are many more ways you can benefit by complete, dependable isolation of fluid and valve working parts. Crane Packless Diaphragm Valves are equally effective under corrosive conditions, and on erosive fluids—sludges, slurries, etc. They also keep your product contamination-free. Choose these valves to your needs from a wide variety of body, disc, disc-insert, diaphragm, and lining materials. See your Crane Catalog or local Crane Representative.





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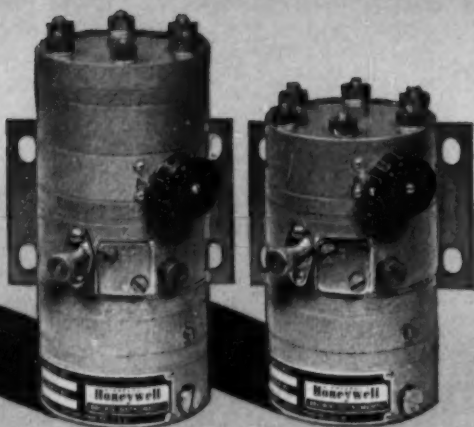
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### ★ two-mode controllers

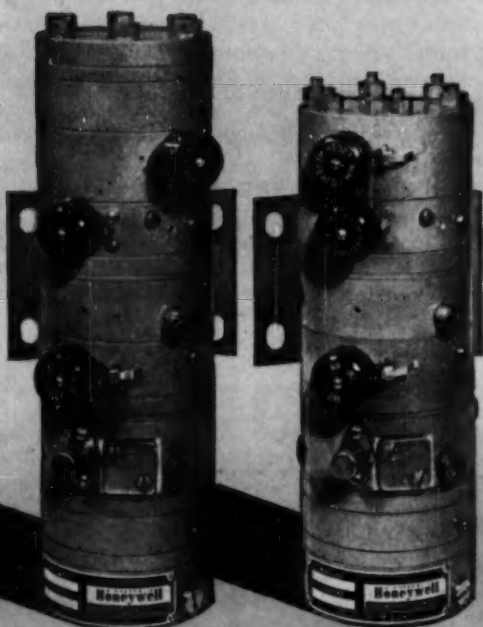
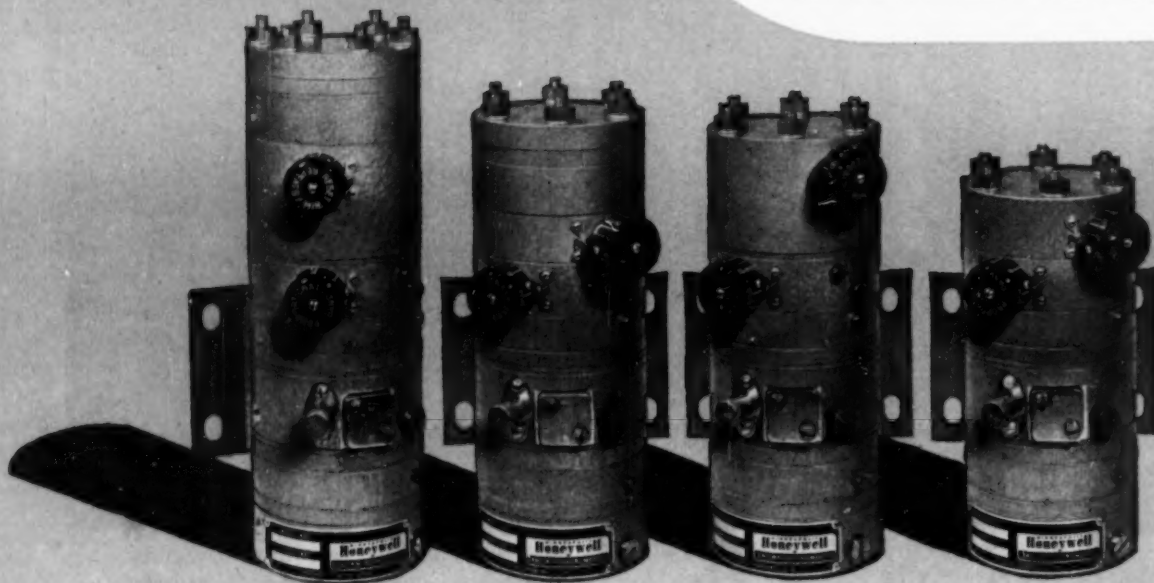
#### *Fixed band plus reset*

Amplly sensitive for many processes, these models have proportional band set at 150%. Especially designed for flow applications, with reset action adjustable from 0.2 to 100 repeats per minute. Available with or without integral by-pass relay.

### ★ two-mode controllers (Below)

#### *Adjustable band plus reset*

For processes with short time lags, as well as for many having slow response. Proportional band is adjustable from 2 to 150%. Choice of slow reset type—0.01 to 5 repeats per minute, or fast reset type—0.2 to 100 repeats per minute. Both types available with or without integral by-pass relay.



### ★ three-mode controllers

#### *Proportional plus rate plus reset*

The newest additions to the Tel-O-Set line, these controllers are applicable to processes with slow response or long time lags . . . such as are often encountered in temperature applications and in certain pressure control work. During automatic start-up, in particular, rate action *prevents* overshooting . . . brings the process in line more quickly and smoothly than simpler control could do.

All three modes are adjustable. Proportional band: 2 to 150%. Reset rate: 0.04 to 20 repeats per minute calibrated range, increasable to about 70 per minute. Rate time: calibrated range 0.02 to 10 minutes; minimum time about  $\frac{1}{4}$  second. Available with or without integral by-pass relay.

# Choose a **Tel-O-Set** **controller** *for the performance your job requires*

**W**HATEVER your specific application may demand in the way of fast-acting pneumatic control, you'll find exactly the right answer in the *Tel-O-Set* controller family. You can select the model that gives the type of control that fits your specifications to a "T" . . . and not be over-sold nor under-equipped . . . but *just right* in economy and performance.

Each of the eight models offers such *Tel-O-Set* features as sealed-tight design, non-bleed pilot valve, simplified tuning, easily-read dial calibrations. Each utilizes the pneumatic balance principle . . . responds instantly to process changes. Dead zone is less than 0.04 psi. Applications cover pres-

sure, liquid level, flow and temperature.

Designed to work with *Tel-O-Set* miniature indicators and recorders, these compact controllers are unaffected by vibration and ambient temperature changes. They need practically no maintenance . . . can have a split manifold to permit removal of the controller while on manual by-pass.

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# SPARKLER FILTERS

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## FINE FILTERING



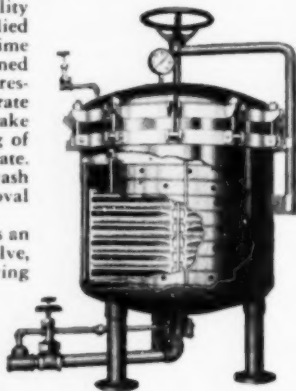
Complete filter cake stability, and the ability of the Sparkler horizontal filter plate to accommodate any combination of filter media and filter aid with maximum efficiency is the reason Sparkler filters meet the most exacting requirements for fine filtering.

The horizontal position of the filter plates permits the use of any kind of filter paper, cloths, or screens; and any grade of filter aid without precoating of fibrous material to hold the cake on the plate. There is no distortive strain on the cake at any time even with varying pressure, interrupted flow, or complete shutdown of filtering operation.

This positive cake stability permits full attention to be given to just the right combination of filter media and filter aid to produce the required quality of fine filtration. A very thin precoat can be applied with low pressure, at a considerable saving in time and filter aid, and fine sharp filtration obtained immediately. The cake built up with reduced pressure is less dense and permits a greater flow rate than where pressure is required to hold the cake in position. No cracking, slipping, or breaking of the filter cake is possible on a horizontal plate. Complete recovery of product is obtained by "wash through" or "blowdown" of cake without removal from the filter.

The Sparkler patented scavenger plate acts as an auxiliary filter with independent control valve, filtering each batch down to the last drop leaving no hold over in the filter.

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**MANUFACTURING COMPANY**

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MANUFACTURERS OF FINE FILTRATION EQUIPMENT FOR MORE THAN A QUARTER OF A CENTURY



Textile Research Institute and the Princeton University faculty. In dozens of fields of activity this sort of collaboration on the job between people who supposedly represent contrasting elements in our society is taken as a matter of course.

The truth is that we Americans are great joiners, organizers, cooperators, coordinators and conference-goers; whenever one of us has a bright idea he wants to form an association to promote it. And while our interdependence causes the government to grow hugely, so it also brings forth a lively abundance of private organizations—the characteristic mark of an unregulated and unregimentable people.

—Frederick Lewis Allen

Author and former editor of  
Harper's Magazine  
Life Magazine, Jan. 5, 1953

### The Spirit That Quickens

Academic freedom is important to us all because knowledge is important, because the search for knowledge is important, and because the spirit of the search for knowledge is most important of all. . . . To the seeker after the truth all horizons are eternally open. . . .

The business of the university is not so much the guardianship of knowledge as the search for knowledge, the keeping open of the intellectual horizon. . . . The one institution supremely dedicated to the spread of enlightenment is the institution of learning. Its individual members have interests and prejudices and passions like other men. . . . But together, each in his own field, they seek for knowledge, and thus the institution is redeemed. It is the belief in the supreme importance of the freedom to seek knowledge which unites them.

Without that belief and its triumphant vindication in our colleges and universities the right of a man to think for himself, to inquire, to have his own opinions, would lack any sure foundation. Democracy, in a world of incessantly whirling propaganda, would have no strong defense. And civilization, what remained of it, would become no more than a mesh of techniques designed for the enslavement of body and mind. . . . Only the spirit that animates the endless search for knowledge can save us from these things. This spirit must continue to flourish outside our universities as well as within their walls. . . . it is the spirit that repudiates the right . . . to establish a censorship over the expression of opinion. . . .

—Robert M. MacIver, Sociologist  
Columbia University

New York Times Magazine, April 12, 1953



**"Non-stop" vulcanizing now faster,  
more uniform than ever...**

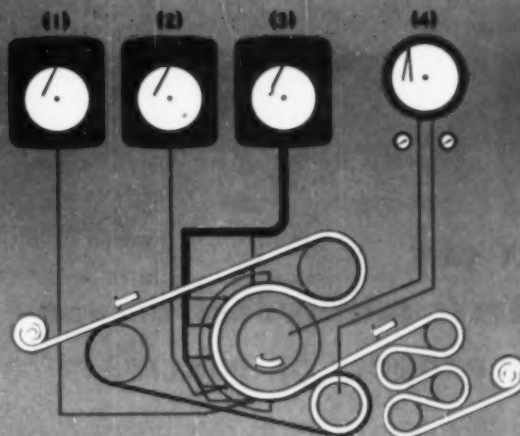
Accurate, sensitive Foxboro Controls have played a vital part in the success of Boston Woven Hose & Rubber Company's "Rotocure", which permits continuous uniform vulcanizing of belting . . . eliminates waste and over-cured sections.

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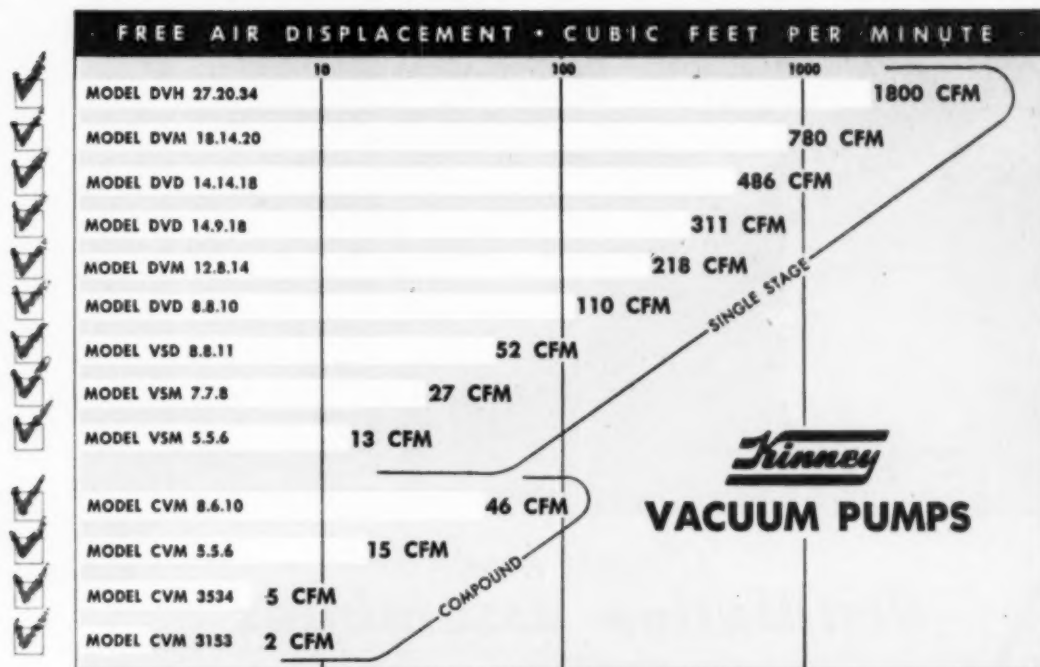
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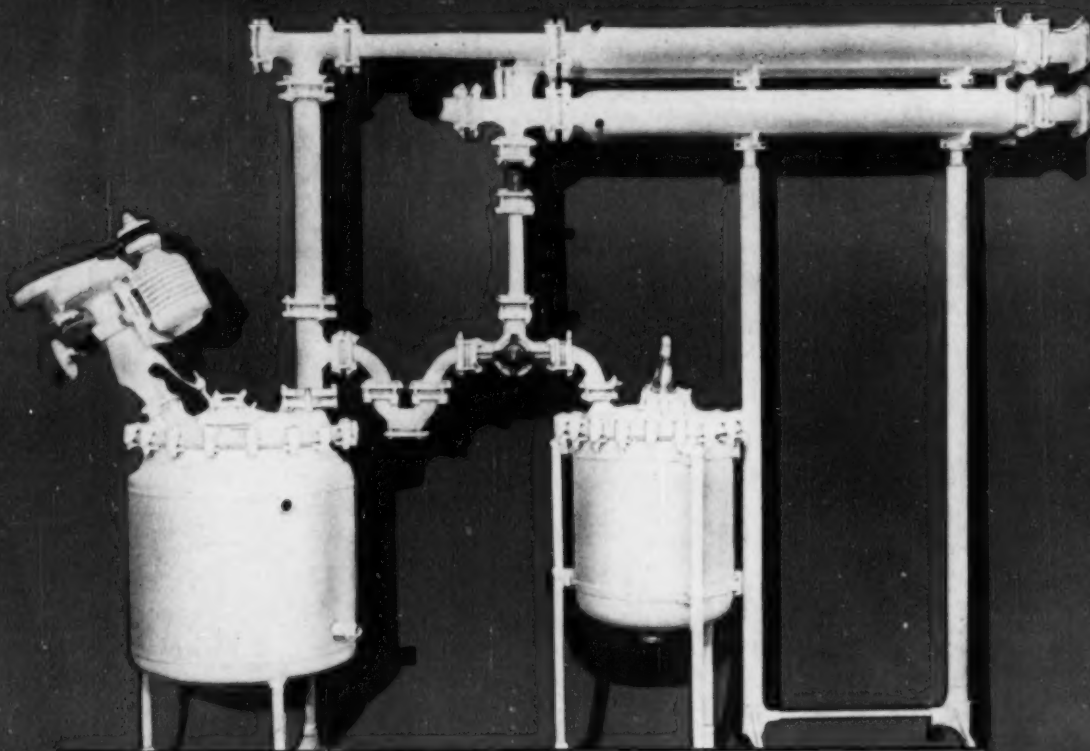
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# Opinion and comment

## ENGINEERING ENTERS THE PENUMBRA

"There's glory for you."

"I don't know what you mean by 'glory,'" Alice said.

Humpty Dumpty smiled contemptuously. "Of course you don't—till I tell you. I meant 'there's a nice knock-down argument for you.'"

"But 'glory' doesn't mean 'a nice knock-down argument,'" Alice objected.

"When I use a word," Humpty Dumpty said in rather a scornful tone, "it means just what I choose it to mean—neither more nor less."

"The question is," said Alice, "whether you can make words mean so many different things."

"The question is," said Humpty Dumpty, "which is to be master—that's all."

A fantastic "Through the Looking Glass" episode has just come to our attention, and today the question is, "what is the definition of the word *engineering*?" and possibly, "which definition is to be master, the legal or the historical?"

We refer to the efforts of the Engineers Joint Council under the laws of the State of New York to become a nonprofit corporation. Even though this legal situation occurred in New York, its implications concern all those who answer to the honorable and ancient title of Engineer. The story on page 32 of the News section of this issue tells of the opposition of the New York State Society of Professional Engineers to the incorporation of the E. J. C. solely on the grounds that the word *engineers* is used in the title.

There is no question that, temporarily at least, the licensed engineers have the legal argument on their side, for the law in New York enjoins "... nor shall any corporation hereafter formed use or assume a name involving the word *engineer* or *engineering* or any modification or derivative of such terms except a nonprofit membership corporation composed exclusively of professional engineers." How such a law ever got past the engineering societies is a mystery to us, but there it is being used to prevent the legitimate, benign, collaboration of the engineering societies.

When licensing protection was given to the engineering profession, it is doubtful that the intention was to prevent both licensed and unlicensed engineers joining together to promote the profession. Licensing was intended to protect the public from malpractice, to guarantee that when one hired an engineer to design or to survey, he had passed a minimum requirement of examination and practice. The law was not intended to foster intraprofessional fights for power, nor did it give to the licensing societies exclusive ownership to the word *engineer*. It certainly did not bestow the right to speak for the engineering profession, for no one speaks for the engineering profession—its accomplishments speak for it!

We have just finished celebrating the one hundredth anniversary of the first engineering society in the United States, the American Society of Civil Engineers. When it was formed, permission was sought from no person. It was organized because of a need. Surely, it is impossible to argue that the formation of this society, and of the seven others that now form E. J. C., was bad for engineering! How then could it be supported that a joint organization of these societies, formed to work out mutual problems in the engineering profession, is bad for any segment of the engineering profession—licensed or unlicensed?

Engineering is a way of thinking, a way of doing. Its purpose is not to provide legal assurance for a certain group to feel vainglorious in a certificate from the state. Being an engineer is far deeper than that. Our primary concern is with the necessities and comforts of mankind, and no license, no legal right to *do* has ever accomplished anything.

The calling of engineer, the term, the very words that are so prideful to the licensed engineers were brought to their high regard in the public mind not by legal rights, not by certificates to practice, but by Engineers, with a capital *E*, who knew deep down that professions, like men, are judged by deeds. The action of the New York State Society of Professional Engineers, in opposing the incorporation of the Engineers Joint Council, was a mischievous bit of business that could result in more harm than good to the profession. It smacked of the guild type of mentality, and if this presages the future course of engineering, if this is to be the use of the legal powers granted to the profession, then indeed we are entering the shadows.

Unless our sights are trained on the higher and more valuable purposes of our profession, we shall cease to be one and become instead merely partially paid technicians in the employ of forces we neither control nor influence. If this is to be the type of action held up to the public and to the newcomers to our calling as the proper way of protecting an engineer, may we predict something? There will be a race between the proponents of licensing and unionization, and we are certain that the union will finally win out, for truly it appeals more powerfully to the subprofessional instinct.

Then, some day, a new type of man must arise from the ashes of the engineering profession. Whether he will call himself an engineer will be doubtful, but this much will be true: He will lead, he will know, and he will know that he knows. From this new man will come the inventions, the advances, and the progress. And carrying out his orders, following in his footsteps, will be a horde of subgrade technicians, carrying their union cards or other licenses like so many barbers or taxi-cab drivers.

- kept closed during operating cycle
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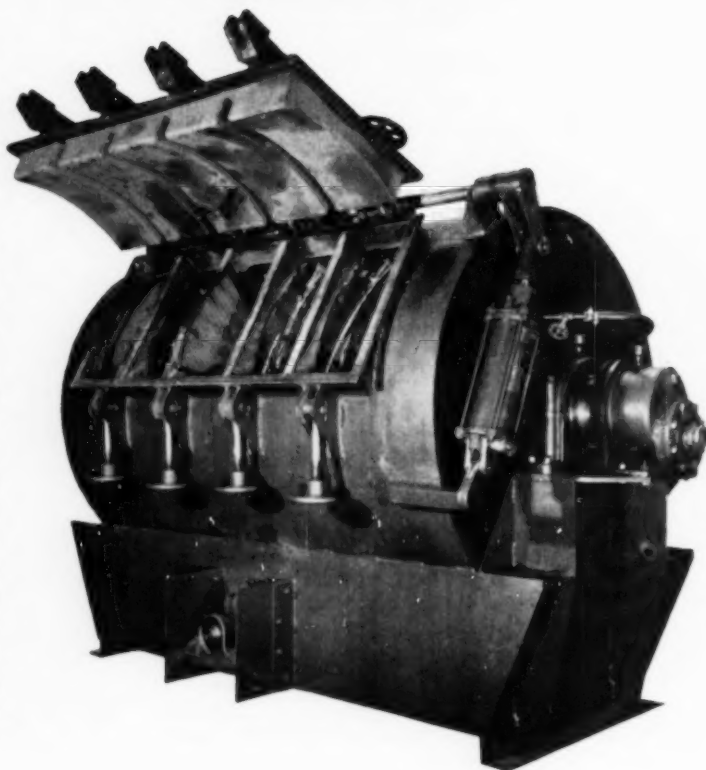
## Conkey Rotary Leaf Pressure Filter

**Conkey Rotary Leaf Pressure Filters** are kept totally closed during the entire operating cycle. This closed cycle operation means safer, more economical operation, less cloth expense. Volatile liquids are handled with negligible loss. Danger to operator from corrosive liquids is minimized.

These Conkey units eliminate the heavy manual labor usually associated with cyclic pressure filtration. Ingenious design requires only valve manipulation for all filtration cycles, including cake discharge.

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# THE NEW PATENT LAW

## HOW DOES IT AFFECT THE CHEMICAL ENGINEER?

P. L. Young Standard Oil Development Co., Elizabeth, New Jersey

The United States patent system has been in existence for more than 160 years and essentially in its present form since 1836. This paper will not cover the value of this system, or trace its growth and influence on the development of the country's industry, but rather get right down to the particular problem of what the chemical engineer should know about patent law.

Those who are taking up the study of patents for the first time are fortunate that a new patent law went into effect on Jan. 1, 1953. It is known as the Bryson Law, Title 35, U. S. Code. It is relatively easy reading and reflects the work and care that went into its becoming a reality. This is the first major piece of patent legislation since about 1870.

The first step was to ask the Patent Office to make a preliminary draft, and every conceivable suggestion that had been made over the last fifty years was introduced into this draft. These included provisions for compulsory licensing, taxation, patents of addition, modifications of the term of the patent and various other changes in appeals and interferences. It was intended to bring these matters up for discussion and it succeeded in this purpose.

Bar associations and patent-law societies all over the country took part in this discussion and the draft furnished an excellent program. Gradually, it became apparent that the overwhelming opinion was unfavorable to any radical changes in the present law.

Finally, a committee representing the societies and associations was selected to

prepare a second draft which was subsequently introduced as a bill by Representative Bryson. And after further discussions and hearings, and still more changes were made the committee finally agreed on the text which was passed by Congress and signed by the President. This represented more than two years' work.

This law represents about 90 per cent of a codification of the existing law with minor technical changes, and about 10 per cent broader changes which were, in the main, long desired and generally noncontroversial. Some of these changes are important. They have a particular bearing on the chemical industry.

The first important change in the law deals with the subject of contributory infringement and re-establishes this doctrine after it had been practically eliminated by the decisions of the courts. Direct infringement is, of course, as is known, the performing of the series of acts specified in some claim of a process or method, patent or the acts of making, selling or using, the machine or product defined in a product patent claim. Heretofore, in order to defeat the patentee, various plans had been concocted by would-be chiselers to perform less than all of the acts enumerated in a claim, or to make less than the whole of the particular patented device, leaving it for the customer, for example, to complete the infringement by adding some conventional item which had to be included in the claim to make it complete. In one of the earliest cases<sup>1</sup> of this sort, the

<sup>1</sup> *Wallace vs. Holmes*, 9 Black. (1871).

patent claim called for an oil lamp consisting of the oil reservoir, the wick-holding assembly and the glass lamp chimney. One manufacturer simply omitted the glass chimney, knowing and relying on the fact that any one could obtain the chimney and complete the structure.

It was, of course, classic law that there is no direct infringement unless all the items of the claims are present, so that one who did less than all of the acts would not normally be held as an infringer. Such a plan would, if successful, allow the manufacturer thus to escape the charge of infringement and it would be inconvenient, if not entirely impossible, for the patentee to sue the numerous customers spread over the country. His rights then would be nullified.

About eighty years ago, the courts realized this situation and originated the doctrine of contributory infringement which, in effect, stated that a substantial infringement such as just mentioned, omitting merely some conventional item, and particularly where it is a part of a scheme or device to defraud a patentee, will be considered a complete infringement of the patent. In the lamp case, the court held the manufacturer to be an infringer. This solution of the problem satisfied everybody but the contributory infringer and was considered a permanent fixture. It was in conformity with other tort law of joint tort responsibility.

It was this solution that was completely erased by recent Supreme Court decisions reversing the prior holdings,



P. L. Young

After graduation in 1920, Philip L. Young spent an additional year at M.I.T. and was awarded a Master's degree in chemical engineering. He was employed for about two years with Eastman Kodak Co. and then entered the employ of the Standard Oil Development Co. as a chemical engineer. An assignment with the patent department of that company awoke a strong interest in the patent law and he undertook a serious study of that subject, graduating from New York University Law School in 1931 and being admitted to the New York Bar in 1932. Mr. Young has been for many years manager of the patent division of the Standard Oil Development Co., with an office in Elizabeth, N. J.

not all at once but over the last twenty or thirty years and greatly weakening patent protection.<sup>2</sup> The new Bryson Law attempts, then, to re-establish this doctrine of contributory infringement and makes such a practice unlawful. (See Sec. 271-b, c, and d.) The new law states that inducing another to infringe is in itself an infringement and this provision furnishes a new chance to plug a bad hole in the patentee's protection.

The second change brought by this bill relates to the new use of an old product and it is somewhat similar to the change just discussed. Suppose that some known chemical compound is discovered to have some valuable property hitherto unknown. Under classic law, any patent on a new product covers that product for all of its uses, so that it would be completely inappropriate now to give a patent on a compound which had been known previously. The problem is how to award the discoverer for his new discovery without taking away from the public what it already had or knew. The new law states that the new use—and this probably means the process for using this old compound so as to take advantage of the hitherto unknown property—may be considered inventive. (See Sec. 100b.) Such a claim would probably not relate to the product per se, and, if such a claim were allowed, it would probably be interpreted to cover only the process of its new use. This means that chemical manufacturers must be on their guard and watch to whom they are selling. If the materials are not ordinary articles of commerce capable of substantial noninfringing use, they must avoid inducing any one to use even known compounds in an infringing manner. Even a sale may be unlawful if obviously for the express purpose of infringement by the purchaser. Difficult questions undoubtedly arise in the interpretation of this portion of the law. It certainly will not cover the sale of ordinary products of commerce such as sulfuric acid, soda and the like which are in broad and general use, and it is difficult to see exactly where the line will be, but it will not permit manufacturers to produce even known substances for which there is now no substantial commercial use and to suggest that their customers use such material according to the disclosures of the patentees who have discovered some hitherto unknown use for the particular compound. This is a similar situation to the use of D.D.T. insecticide and some of the newer drugs, and it is likely that this pattern of facts will recur. It must be recognized that this places a new

burden on the public, but it is in exchange for the right to obtain protection.

The last, or third, change made in the bill attempts to correct the great hazard of inventorship. As understood, a patent must be issued in the name of the true inventor or inventors; otherwise it is absolutely invalid.<sup>3</sup> The inclusion as a joint patentee of one who was not truly an inventor, or the omission of one of the true joint inventors, is fatal. When this provision was originally made, the particular problem presented a few difficulties, but in modern research laboratories it presents a major headache for patent attorneys, and the penalty of absolute invalidity seems too severe. The new law seeks to ameliorate the situation by providing for the correction in this respect, even after the issuance of a patent, where the mistake was made without fraudulent intent. (See Sec. 256.) This is a long-needed correction.

But the reading of this new statute will not be all that is required of you, and you must set out on a more comprehensive program of learning what the patent law is all about. There is much law that is not contained in the statutes and this is because the statutes are like maps of a country; if they are to show all the details, they would be as big as the country itself; and, like maps, they are useful only to simplify complex originals. Almost every word in the statutes must be interpreted, so that it is the interpretations that you will have to study.

### Major Points to Investigate

**Appreciation of Idea of Patentability.** This is not mere novelty but is novelty with an additional creative unexpected content that carries it above the product of the routineer, to use Judge Learned Hand's expression.<sup>4</sup> It must include this "something" which is a cut or two above the product of the ordinary good technician. The particular degree of excellence or unobviousness which is required can be understood only by the study of many illustrative examples.

**Keeping Records Is Important.** One should find out what records are necessary and how they should be kept, and the information must be nailed down by specific examples of how valuable rights were lost by failure to preserve essential records in provable form. When you read such a story, don't feel that this was necessarily due to some fault in the patent law, because the fault is really in the foolish inventor who, after doing the really hard work of invention, finally allows the reward to slip through his fingers by failure to preserve adequate

proof of what he has done. Proof in this matter is absolutely essential to avoid fraud.

**The Essentials of Invention.** The "conception" of an invention and of a reduction to practice involves many steps. In general, these are straightforward, but there are some pitfalls. Certain things, required by the law, must be met and what they are must be understood. What tests are required to constitute a valid reduction to practice? One needs a demonstration of the invention on a scale and in such a manner that it is convincing of satisfactory commercial use without the requirement of other experimental work. This must be settled with regard to the particular field with which one is concerned because the requirements as to tests do not seem to be completely uniform throughout the arts; sometimes laboratory work is sufficient, but sometimes it is not and a larger scale is required. The only general rule is that, whatever demonstration one uses, it should simulate actual working conditions as closely as possible. It is this author's prediction that a prospective inventor would be surprised at what he would find in respect to the particular fields, for example, of insecticides,<sup>5</sup> medical preparations,<sup>6</sup> and the like. In this, and in some other instances, in the writer's opinion, the law has gone astray and does not always represent the normal opinion of those most skilled in the art.

**Tests and Corroboration.** Tests are unreasonably severe in the matter of corroborating an inventor's testimony on his acts constituting the making of inventions. Stated simply, the records and testimony of the inventor himself are just never sufficient for the court. Proof of the fact and date of his invention must be presented by some other witness. Ordinary reports, letters and other documents prepared in the ordinary course of business, should be sufficient evidence of the facts represented just as in other branches of the law, but the courts have ruled otherwise in the case of an inventor, and the corroborating witness must be able to say that he saw particular experiments and understood them. It will not be enough for him to testify that he was in and out of the laboratory every day, or worked alongside of the inventor and knew what he was doing, if he cannot swear that he actually saw the particular trials relied upon and, in effect, duplicate the inventor's testimony.<sup>7</sup> In one case, the court complained that the corroborating witness had not read the thermometer.

<sup>2</sup> *Morgan Envelope vs. Albany Paper Co.*, 152 US 425 (1912).

*Mercoind Corp. vs. Mid-Continent Investment*, 60 USPQ 21 (1944).

<sup>3</sup> *United Chrom. vs. Gen. Motors*, 31 USPQ 105 (1936).

<sup>4</sup> *International Vitamin Corp. vs. Squibb & Sons*, 17 USPQ 415 (1933).

<sup>5</sup> *Smith vs. Bousquet*, 45 USPQ 347.

<sup>6</sup> *Ex parte Wolf*, 65 USPQ 527.

*Morton vs. N. Y. Infirmary*, 2 Fish. 320.

<sup>7</sup> *Bainbridge vs. Walton*, 42 USPQ 138.



**Interference Practice Is Technical.** It has many surprises. An interference, as is known, is a contest between rival inventors who have claimed the same invention. The object of the proceeding is to determine which of the inventors is the first. In such a proceeding, the contested claims are selected by the Patent Office but these may be modified by the parties on motion for that purpose. Sworn statements are required of the contestants on the particular dates of the acts which, if proved, will set their claim for the earliest date for the making of the invention. When these dates are set forth, they cannot be changed except under extraordinary circumstances. They are limiting, and, in subsequent proceedings, if a contestant actually proves dates earlier than those which he has set up in this preliminary statement, it will avail him nothing and he will be restricted to those dates which he has put in the statement. There are motions by which, under suitable circumstances, the interference may be dissolved. The burden of proof may be shifted also from one party to the other, and other related issues may be brought into the interference for settlement.

All these matters are important and it should be carefully noted that, if a contestant does not speak up at the particular time when he should, he may be thereafter estopped. Thus, seeing an opponent's application, a contestant should determine whether he has any claims to any invention or specie disclosed by the opposing inventor other than the one in the contested counts. If there is such overlapping subject matter and the contestant fails to bring it in at the proper time, then he may be estopped thereafter and he will not obtain the patent on that particular overlapping subject matter, no matter how much earlier his dates may have been. Under certain circumstances, such losses may occur. Testimony of the inventors and the witnesses is then taken just as in court and much the same general rules apply. Interferences are often a great bugbear to the inventor because they are expensive and, at first sight, they seem so complex. Indeed they are complex, but still the interference is a proceeding that one must know at least something about so that he can cooperate properly with his attorney in the protection of the inventor's rights.

**How Full Must the Disclosure Be?** This is a question frequently asked. This author suggests abandoning any ideas on being slick, that is, leaving out a few essential details in the hope of preserving a valid patent without giving away the essence of the discoveries. An inventor should learn to study his invention to determine the proper breadth or scope of the claims from a consideration of the prior

art, and then carefully design the disclosure, and especially the working examples, to illustrate and conform to the concept of this maximum breadth. The number of examples is much less important than their variety, especially as to starting materials, operating conditions and the like. These should be chosen with an eye on range and scope so as to illustrate the areas which an inventor expects to protect in his claims. Concrete examples of success, but especially of failure, in these matters make the best lessons. The best rule is, of course, that the disclosure should be sufficiently full and clear to enable any one skilled in the art to produce inevitably the inventor's result and to understand what other materials could be substituted and what ranges of pressure, temperature and other conditions would be expected to operate properly.

**The Validity of Patents Is Puzzling.** This is especially true when there may be two valid patents covering one and the same process, one and the same chemical process or device. Doesn't the United States patent, on its very face, say that the patentee has been given the exclusive right to practice this invention? Yes, that is what it says, but it just doesn't mean it. A patentee is given the right to *exclude others from using his invention*. It should be understood that two such patents cannot be of the same scope. Thus, one patent may cover a series of steps in the process, and another may cover the same series with the addition of one more step, so that it will be clear that the second patentee, in practicing his invention, would be using the invention of the first, which he may not do. In this way, a third person might well need the protection of both patents. This illustrates the nature of a dominant or basic patent and a subservient or improvement patent. It is understood that this applies also to machines and to products.

#### **Rules Applicable to Chemical Inventions.**

These rules deal with the scope or breadth of claims as limited by breadth of disclosure which are of first importance, special rules as to change of proportions of mixed ingredients, and special types of claims that have particular advantages when used in certain circumstances. There is here a body of law that will be filled out slowly and which develops month by month. This is the portion of the field which is growing under the impact of creative chemistry and, in this author's view, some real progress is being made on the question of the relation between disclosure and scope under different circumstances, which seems to be the center of the difficulties in the drafting and interpretation of the chemical patents.

**Assignments and Licenses.** One should learn what he can do with his patent without running afoul of the Anti-Trust laws. Something about assignments, grants or licenses, in a general way, will be of interest. A prospective patentee should know how to read a patent and find out, at least in a tentative way, what it means and what it covers. He should be able also to draw a provisional opinion on probable validity in view of the art, and probable infringement knowing what the particular steps may be. This knowledge will be of great help in working out plans and researches, for example, in efforts to avoid infringements, although to be final they should be rechecked with one's attorneys. This author is not referring to avoiding infringement in a cheap or disparaging sense, for one should not pay royalties except for rights under a valid patent which teaches and claims what is used, made, done or sold. This is a real advantage of the patent system. It encourages competition in research to find other improvements in methods or products which can displace those which have been patented.

**Patent Structure.** It may be well worth while to study the patent structure that has been carefully built up in different fields to note how these patents combine one by one, building up a structure to protect a valuable investment.

In conclusion, it should be stated that the patent law is important to the growth of any democratic country; there will always be a place for incentive and reward for value received in the form of a new teaching. Generally, it is believed that the U. S. patent system is the best one and takes its origin from two of the most important thoughts characterizing our Western Civilization: first, the systematic use of natural science in the service of mankind, and, second, a systematic method of reward to encourage those more gifted ones who can contribute to the advance of the Western Civilization. This reward is not set by some commission or board, but in the free market and that is what makes it right. It is fixed by the dollar-and-cents value of the contribution. So long as interest in individual rewards and incentives continues, the patent law will have a place in our civilization. So long as citizens of this country are confident and eager to use nature for the benefit of mankind, patent law can justify that place. For further growth in the chemical industry it is necessary that the chemist and the chemical engineer have a real understanding of the patent law and its principles.

*(Presented at A.I.Ch.E. Forty-fifth Annual Meeting, Cleveland, Ohio.)*

# ATOMIZATION BY CENTRIFUGAL PRESSURE NOZZLES

## Part II

It was desired to establish the effects of basic nozzle properties on spray characteristics. Three fundamental variables, therefore, were believed sufficient to describe any pressure nozzle operation and design: (1) the diameter of the nozzle orifice, (2) the liquid vertical velocity component, and (3) the tangential velocity component of the liquid. Thus, internal design features would be interpreted in terms of tangential velocity, while the vertical velocity component would be related to the pressure.

The vertical velocity,  $V_v$ , of the liquid leaving the nozzle was arbitrarily computed on the basis of the orifice cross section as follows:

$$V_v = \frac{0.407C}{d_o^2} \quad (8)$$

where

$V_v$  = vertical velocity component, ft./sec.

$C$  = capacity of nozzle, gal./min.  
 $d_o$  = orifice diameter, in.

Equation (8) is based on the assumption that the orifice runs full. This is not the actual case, however, and is discussed later.

The liquid inlet tangential velocity,  $V_t$ , for grooved core nozzles was determined from the following equation:

$$V_t = \frac{0.32C(\cos \alpha)}{N_g A_g} \quad (9)$$

where

$V_t$  = inlet tangential velocity component, ft./sec.

$\alpha$  = angle made by grooves with the horizontal

$N_g$  = number of grooves

$A_g$  = cross-sectional area of a single groove, sq.in.

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TABLE 1.—DATA FOR TESTS TO DETERMINE EFFECT OF TANGENTIAL VELOCITY ON DROP SIZE

Spraying Systems Nozzles

$d_o = 0.031$  in.

$V_v = 80$  ft./sec.

Run	Core	$p_i$ lb./sq.in.	$C$ gal./min.	$V_t$ ft./sec.	$D_{15}, \mu$	$D_{50}, \mu$	$s$ ( $\mu$ ) <sup>1/2</sup>	$\theta_{NO}$ degrees	$\eta_{15}$ %
1	16	891	0.189	47.45	43.3	51.8	1.45	76.5	0.141
2	17	420	0.189	23.68	54.3	62.0	1.60	68.5	0.239
3	21	285	0.189	12.95	60.0	68.6	1.85	61.0	0.318
4	27	153.3	0.189	7.59	63.4	72.0	1.90	49.5	0.560
5	None	60.4	0.189	0	351.9	481.7	6.3	0	0.256

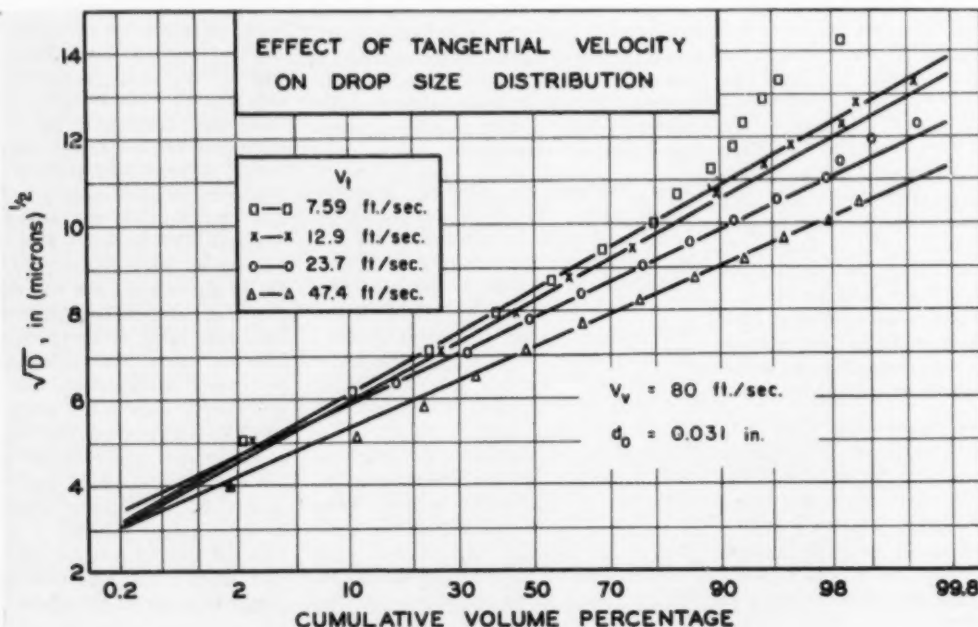


Fig. 9.

TABLE 2.—DATA FOR TESTS TO DETERMINE EFFECT OF VERTICAL VELOCITY ON DROP SIZE

Spraying Systems Nozzles									
$d_o = 0.031$ in.				$V_t = 23.68$ ft./sec.					
Run	Core	$\rho_c$ lb./sq.in.	$C_c$ gal./min.	$V_{c_s}$ ft./sec.	$D_{V_{c_s}}$ $\mu$	$D_{V_{c_s}}$ $\mu$	$s_z$ ( $\mu$ ) <sup>1/2</sup>	$\theta_{80^\circ}$ degrees	$\eta_{80^\circ}$ %
5	16	222	0.094	39.9	63.1	70.4	1.50	74.5	0.388
2	17	420	0.189	80.0	54.3	62.0	1.55	68.5	0.239
7	21	950	0.344	146.0	49.7	56.1	1.50	53.5	0.115

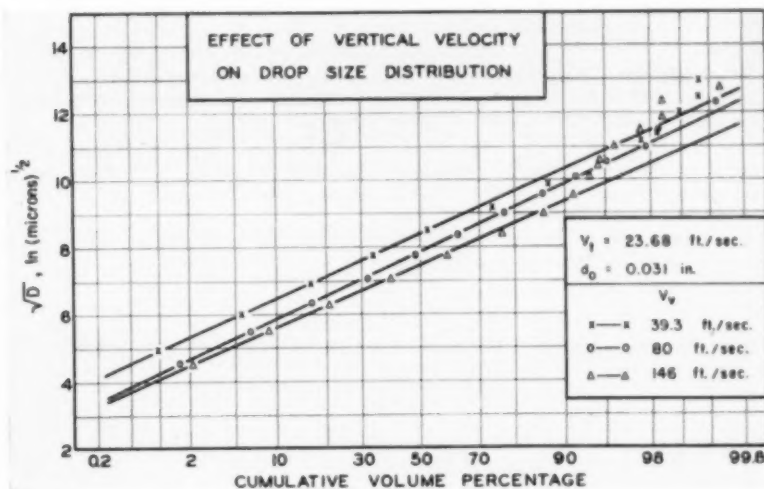


Fig. 10.

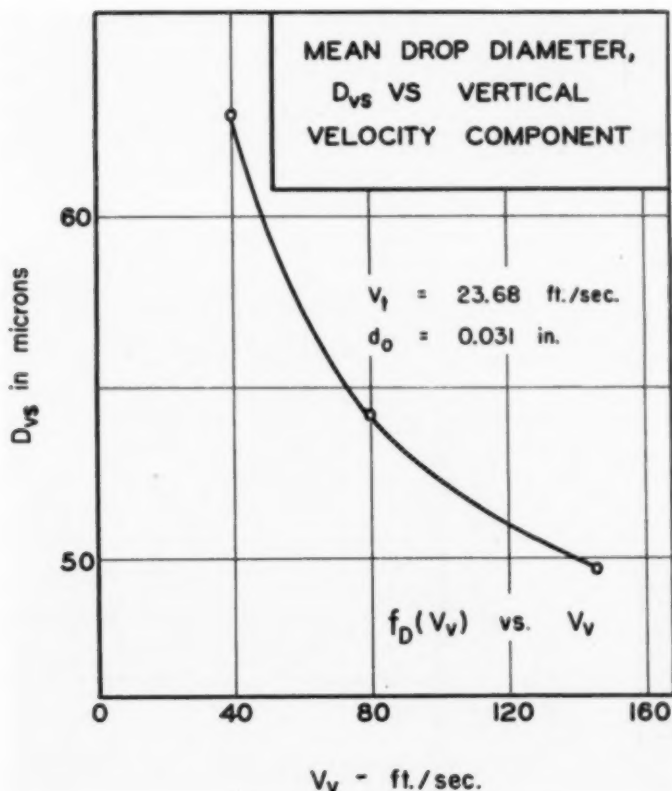


Fig. 11.

Appropriate combinations of cores and operating pressures were chosen so that  $V_v$  and  $V_t$  might each be varied while the other was held fixed. In Table 1 and Figure 9 the conditions of operation and drop size data for varying  $V_t$  at constant  $V_v$  and  $d_o$  are given. Table 2 and Figure 10 give similar data for the runs with varying  $V_v$  and constant  $V_t$  and  $d_o$ . Figures 11 and 12 show the variation of  $D_{VS}$  with  $V_v$  and  $V_t$  respectively.

It was found that the square root of the drop size plotted against cumulative per cent less than size on a probability scale gave a better fit than either a normal probability plot or a log probability plot. However, such a representation of size distribution was purely empirical in this study, since no theoretical basis for this relationship was evident. Further work is required to substantiate or disprove this correlation.

The physical dimensions of the orifices and cores did not permit a variation in  $d_o$  for constant  $V_v$  and  $V_t$ . Therefore, a method of correlation was used which did not require this. The data for the runs made for various values of  $d_o$  are summarized in Table 3. The variation in  $D_{VS}$  over the range of operating conditions studied was small, and consequently the effect of  $d_o$  as determined in this study has a low level of significance. In an effort to correlate the effect of  $d_o$ , the following expression for  $D_{VS}$  was postulated:

$$D_{VS} = f_D(V_v) g_D(V_t) h_D(d_o) \quad (10)$$

where  $f_D(V_v)$  and  $g_D(V_t)$  are the values of  $D_{VS}$  corresponding to any given  $V_v$  and  $V_t$  in Figures 11 and 12, respectively. If Equation (10) is rewritten as

$$h_D(d_o) = \frac{D_{VS}}{f_D(V_v) g_D(V_t)} \quad (11)$$

the function of  $h_D(d_o)$  may be evaluated for various orifice diameters by substitution into the right-hand side of Equation (11) values of the functions based on  $V_v$ ,  $V_t$ , and the experimental values of  $D_{VS}$ . This was done for the runs listed in Table 3 and resulted in the relationship between  $h_D(d_o)$  and  $d_o$  shown in Figure 13.

To estimate values of  $D_{VS}$  corresponding to any specified  $V_v$ ,  $V_t$ , and  $d_o$ , the corresponding functions read from Figures 11, 12, and 13 are merely substituted into Equation (10). Use of this equation, however, is restricted to the atomization of water in the following ranges of the variables studied:

$$\begin{aligned} 0 < V_t < 50 \\ 40 < V_v < 150 \\ 0.013 < d_o < 0.04 \end{aligned}$$

where the velocity components are superficial average velocities; i.e.,  $V_t$  is

TABLE 3.—DATA FOR TESTS TO STUDY EFFECT OF ORIFICE DIAMETER

Spraying Systems Nozzles										
Run	Core	$d_o$ , in.	$\rho$ , lb./sq.in.	$C$ , gal./min.	$V_t$ , ft./sec.	$V_v$ , ft./sec.	$D_{VS}$ , $\mu$	$D_{V_{DQ}}$ , $\mu$	$s$ , ( $\mu$ ) <sup>1/2</sup>	$\theta_{SDP}$ , degrees
8	17	0.0135	420	0.067	8.5	151.9	54.4	58.6	1.37	47.0
9	17	0.0200	420	0.102	12.8	104.5	55.0	61.8	1.50	55.5
2	17	0.0310	420	0.189	23.7	80.0	54.3	62.0	1.60	68.5
10	17	0.0400	420	0.248	31.2	63.4	53.3	60.6	1.61	72.5
11*	17	0.0400	420	0.248	31.2	63.4	52.4	60.4	1.65	72.5
12	21	0.0400	250	0.254	17.5	64.9	69.9	81.0	1.92	71.5

\* Run 11 was a check of Run 10 to test reproducibility.

calculated for conditions immediately preceding the orifice, and  $V_e$  is calculated as though the orifice were flowing full.

Figures 1 to 8 appeared in Part 1, April issue.

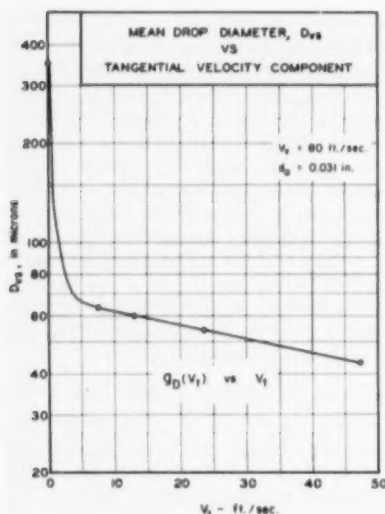


Fig. 12.

It should also be pointed out that Equation (10) is based on the assumption that the three functions are independent. On the basis of this assumption the required quantity of data was materially reduced. To test the reliability of the assumption, a check run was made wherein the operating conditions were dissimilar to those of any previous

run. An analysis of this check run is shown below:

#### RUN 13

Core 16  $d_o = 0.0135$  in.  
 $\rho = 560$  lb./sq.in.  $V_t = 14.60$  ft./sec.  
 $C = 0.058$  gal./min.  $V_v = 130.1$  ft./sec.  
 $D_{VS}$  (determined experimentally) = 51.0  $\mu$   
 From Figure 11,  $f_D(V_t) = 50.4$   
 From Figure 12,  $g_D(V_t) = 59.0$   
 From Figure 13,  $h_D(d_o) = 0.01693$

Hence, from Equation (10),

$$D_{VS}(\text{calculated}) = (50.4)(59.0)(0.01693) = 50.6 \mu$$

This close agreement between the experimental and computed  $D_{VS}$  appeared to confirm the assumption underlying Equation (10).

The relationships in Figures 11, 12, and 13 were combined to obtain the following empirical equation:

$$D_{VS} = 286(d_o + 0.17)e^{(13/V_v - 0.0094V_t)} \quad (12)$$

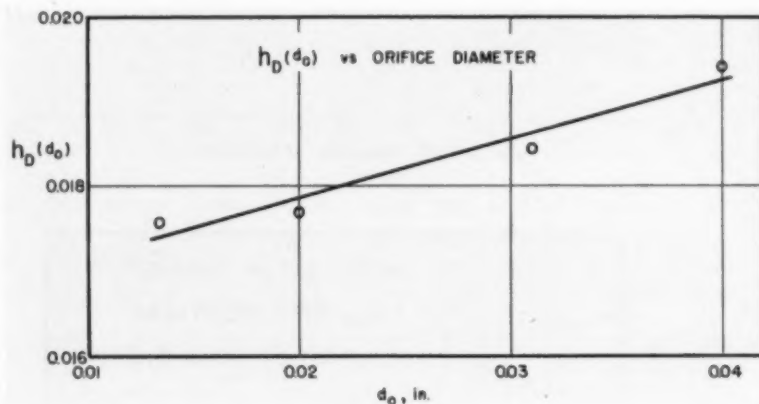


Fig. 13.

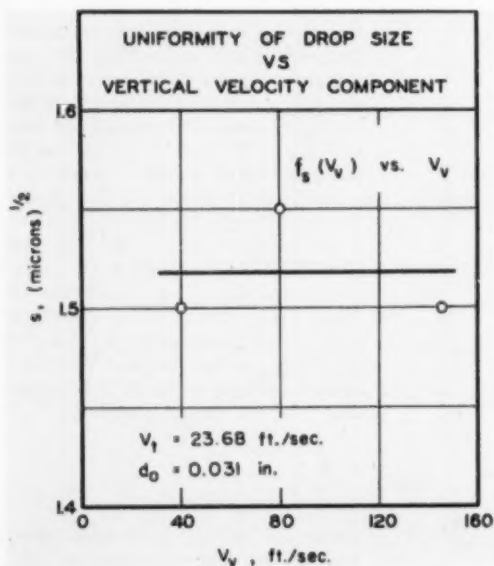


Fig. 14.

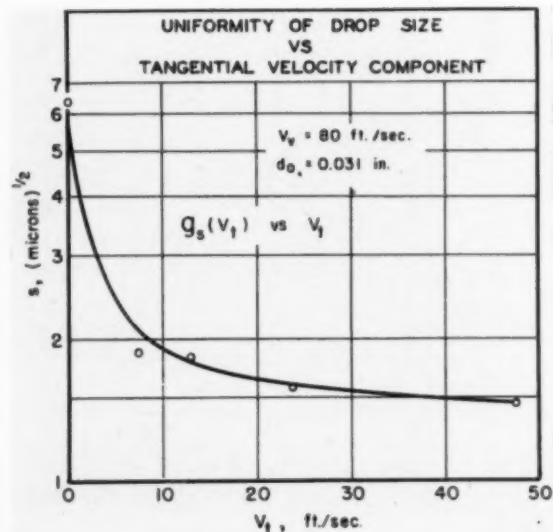


Fig. 15.



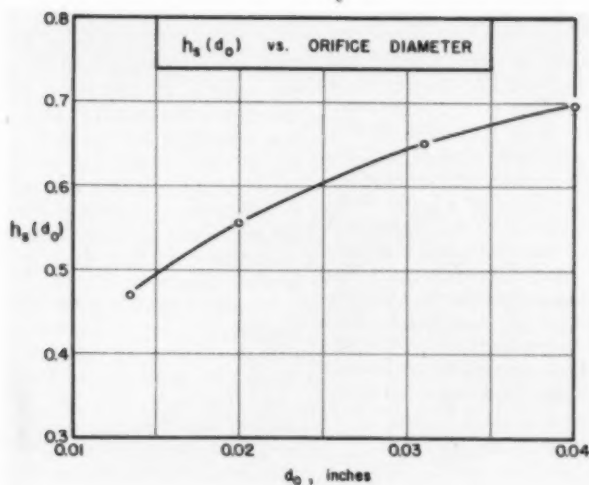


Fig. 16.

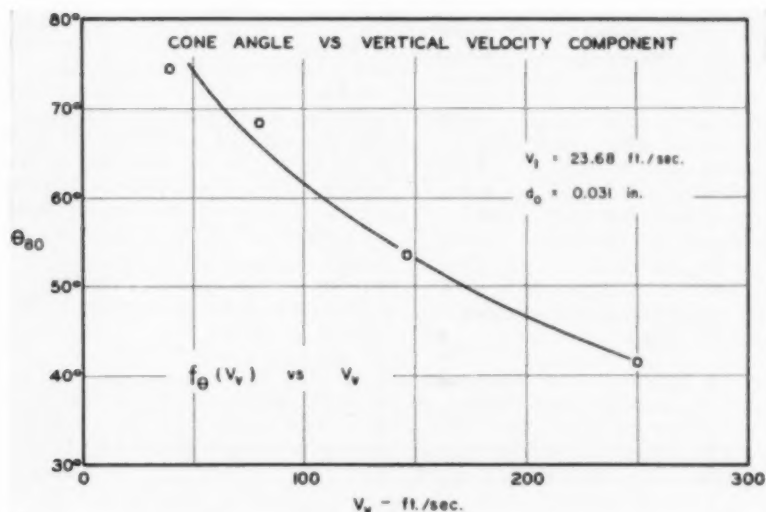


Fig. 17.

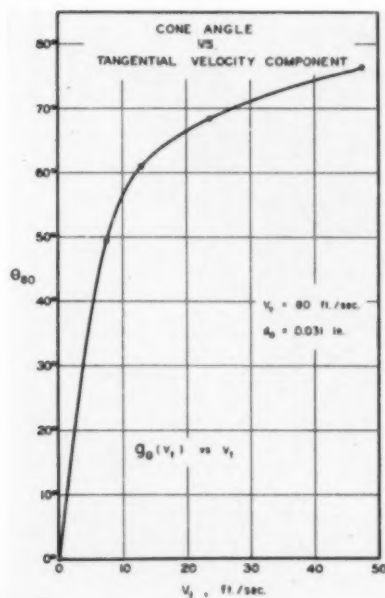


Fig. 18.

Equation (12) is restricted to values of  $V_t$  between 7 and 50 ft./sec. since, for smaller values,  $\log D_{V_{80}}$  vs.  $V_t$  is no longer a linear plot (Fig. 12). The range of  $V_v$  is 40 to 150 ft./sec.

As pointed out earlier, the standard

deviation,  $s$ , is a measure of size uniformity and for a square root type probability plot is given by

$$s = \sqrt{D_{V_{84.13}}} - \sqrt{D_{V_{50}}}$$

Correlations of uniformity of drop size,  $s$ , and  $V_v$ ,  $V_t$ , and  $d_o$  resulted in Figures 14, 15, and 16, from which values of  $f_s(V_v)$ ,  $g_s(V_t)$ , and  $h_s(d_o)$  may be read and substituted into the following expression analogous to Equation (10):

$$s = f_s(V_v) g_s(V_t) h_s(d_o) \quad (13)$$

The variation of  $s$  with  $V_v$  is small as Figure 14 shows, and  $s$  probably could be taken as independent of  $V_v$  over the range studied.

Similarly, by means of Figures 17, 18, and 19, spray cone angles may be estimated using the relation

$$\theta_{80} = f_\theta(V_v) g_\theta(V_t) h_\theta(d_o) \quad (14)$$

where,

$\theta_{80}$  = plane angle, including 80% of the total spray volume, degrees.

The computation of  $V_t$  is dependent on the manner in which liquid is given a vortical motion within a centrifugal nozzle. The foregoing correlations were based on grooved core type nozzles in which  $V_t$  was evaluated at a point immediately above the orifice. For a whirl chamber type nozzle, however,  $V_t$  may be evaluated either at the entrance to the chamber (Fig. 2), which ordinarily is an appreciable distance from the orifice, or at the orifice, where it may differ considerably from the entrance velocity.

In order to extend the preceding correlations to include whirl chamber nozzles, the following expedient was devised. A whirl chamber nozzle operating with given values of  $d_o$ ,  $V_v$ , and cone angle should by virtue of Equation (14) have an effective tangential velocity component,  $V_t$ , corresponding to a fictitious grooved core nozzle as specified by the function  $g_\theta(V_t)$ . If  $g_\theta(V_t)$  can be estimated, then from Figure 18,  $V_t$  may

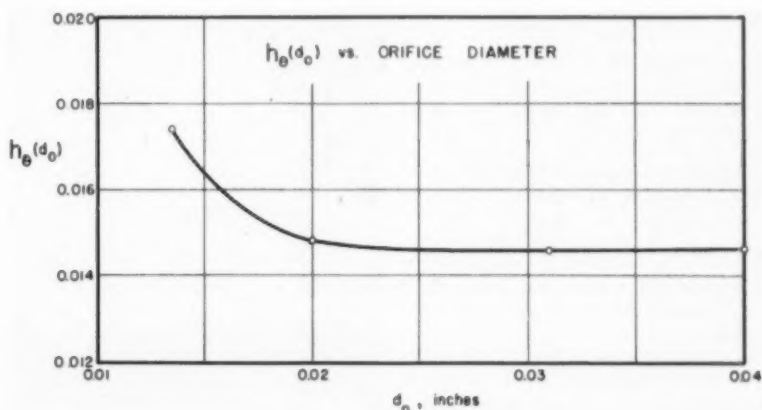


Fig. 19.

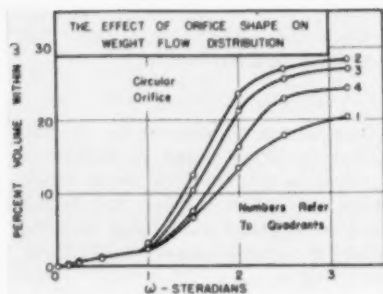


Fig. 20.

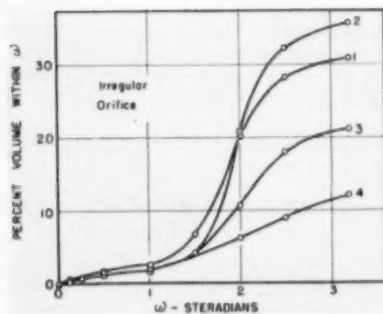


Fig. 21. Distortion of spray distribution due to orifice nonsymmetry.

be determined and substituted into Equations (10) or (12) and (13) to obtain the parameters of drop size distribution. Use of this method requires knowledge of the cone angle for the whirl chamber nozzle, but such data are usually easier to secure than drop size data.

To illustrate this proposed method, data for Run 16, Table 4, will be considered. The measured cone angle,  $\theta_{90}$ , was  $59.5^\circ$ . For a calculated  $V_e = 70.5$  ft./sec., determined from the capacity and orifice diameter,  $f_0(V_e) = 70$  (Fig. 17). Similarly,  $h_0(d_o)$  corresponding to  $d_o = 0.0246$  in. is 0.0146 (Fig. 19). Then substituting in Equation (14) gives

$$g_0(V_e) = \frac{\theta_{90}}{f_0(V_e)h_0(d_o)} = \frac{59.5}{(70)(0.0146)} = 57.9$$

and, from Figure 18,  $V_i = 10.8$  ft./sec. ( $V_i$  calculated at the entrance to the whirl chamber was estimated to be 65.7 ft./sec.) From Equation (12),

$$D_{VX} = 286(0.0246 + 0.17)e^{(13.70)(0.0094X)(0.8)}$$

or

$$D_{VX} = 60.2\mu$$

This value of  $D_{VX}$  is about 10% smaller than the experimental value of  $66.2\mu$ . From Equation (13),

$$s = (1.54)(1.86)(0.597) = 1.71$$

while the experimental value of  $s$  was 1.56.

#### STRAIGHT-EDGED VS. ROUNDED ORIFICE

Comparison of a straight-edged and a rounded orifice at the same pressure (Table 4) indicated that a larger cone angle, smaller drop size, and slightly greater capacity were obtained with the latter. The increase in capacity was explainable on the basis of a lower resistance to flow offered by the filleted orifice. For the same reason, a greater tangential velocity component was probably obtained, resulting in a smaller drop size and greater cone angle. This result points to the desirability of reducing friction losses in nozzles by providing smooth uniform passages for liquid flow.

TABLE 4

	Run 16	Run 17
Nozzle Orifice	Marley Straight-edged orifice	Marley Filleted orifice
$d_o$ , in. ....	0.0246	0.0246
$p$ , lb./sq.in. ...	300	300
$C$ , gal./min. ...	0.104	0.109
$\theta_{90}$ , degrees ..	59.5	68.5
$D_{VX}$ , $\mu$ .....	66.2	61.7
$s$ , $(\mu)^{1/2}$ .....	1.56	1.45

#### EFFECT OF NONCIRCULAR ORIFICE AND TANGENTIAL INLETS

Figures 20 and 21 show the distribution of liquid within each quadrant of the spray cone for each of two orifices, one nearly circular and the other slightly noncircular. The nonuniformity caused

by the latter is evident (Fig. 21).

A similar study showed that spatial uniformity was improved by increasing the number of tangential inlets in a whirl chamber nozzle. This, however, was reasonable because with a single inlet all the liquid entered the whirl chamber at a single point, and, in spite of subsequent turbulence and mixing, did not discharge from the periphery of the orifice as uniformly as it did when several inlets were present.

Results of tests on the effect of the number of inlets on the over-all weight flow distribution of liquid are shown in Figure 22. Comparison of the distributions for one, two, and four inlets showed that the cone angle decreased as the number of inlets increased. This was explained by the recollection that cone angle in general increased with the ratio  $V_i/V_e$ . Thus, if the number of inlets were doubled,  $V_i/V_e$  was halved, regardless of any change in capacity, and a smaller cone angle resulted.

Observations also were made of the variation in weight flow distribution with the angle,  $\beta$ , formed by the axes of the inlets with the inner wall of the whirl chamber. The results are given in Figure 23. Normally, the chamber inlets are designed with  $\beta = 0^\circ$ , as shown in Figure 2. For this case, the liquid enters the chamber smoothly, and  $\theta$  is at a maximum.  $\beta$  may be increased to  $65^\circ$  without affecting spray configuration too significantly, but when  $\beta = 90^\circ$  the two inlet streams oppose one another, virtually destroying any vortical motion. This accounts for the extremely narrow cone angle indicated by Figure 23.

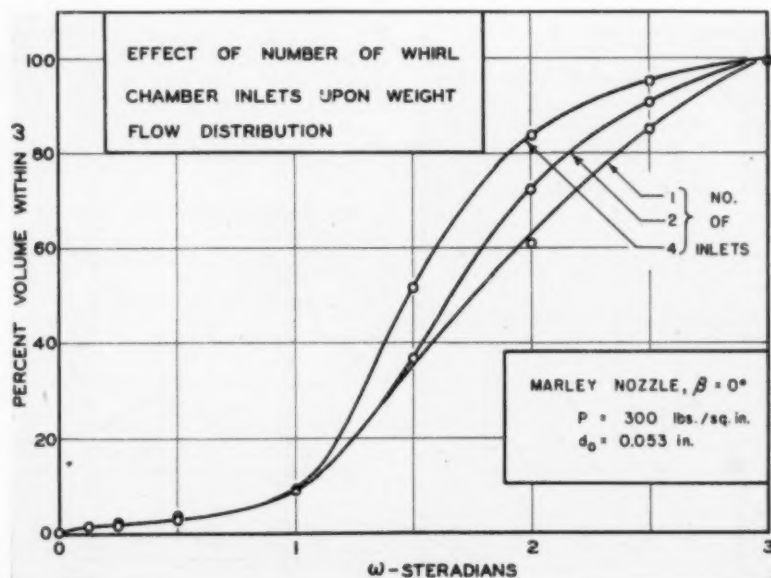


Fig. 22.

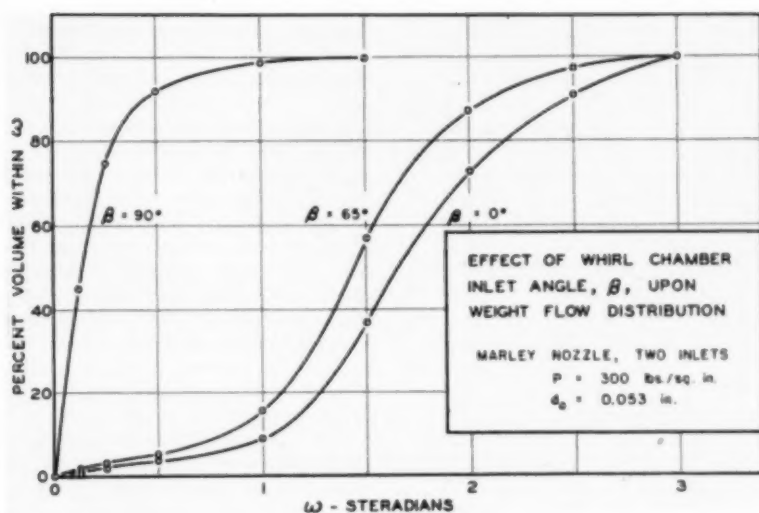


Fig. 23.

#### EFFECT OF VISCOSITY

Preliminary tests were made of the effect of liquid viscosity upon drop size distribution. Three runs at three different viscosities were made at constant capacity,  $V_e$ ,  $V_t$ , and  $d_o$ . The results are shown in Figure 24. In Figure 25 the mean drop size,  $D_{VB}$ , is plotted as a function of viscosity. For the maximum pressure obtainable and the specific nozzle design used, the highest viscosity reported was also the maximum that could be atomized. The results of these tests indicate an obvious trend, but no general correlation of viscosity is proposed at this time.

#### Comments

The correlation of the experimental data was predicated on the assumption of the independence of the functions  $f_D(V_e)$ ,  $g_D(V_t)$ , and  $h_D(d_o)$  in Equations (10).

This assumption was fundamental to the program of the study, for it was assumed that an interpretation of nozzle performance in terms of  $V_e$ ,  $V_t$ , and  $d_o$  would include all the independent factors associated with centrifugal pressure nozzle operation. Thus, the vertical velocity component by virtue of its method of calculation [Equation (8)] is an arbitrary function of the nozzle capacity or nozzle pressure, depending on which variable is most useful.

Figure 26 illustrates the occurrence of an air core in a centrifugal pressure nozzle. This air core is essential for atomization by centrifugal or swirl action in this type of nozzle. The calculation of  $V_e$  was arbitrarily based on the cross-sectional area of the orifice, and it ignored the presence of this air core in the spinning liquid as it left the orifice. Recent tests by Darnell (4a)

with transparent plastic nozzles have shown that the air core diameter for a given nozzle remains relatively constant over a range of pressures and capacities. This observation was verified indirectly in this work from the data on nozzle capacity as a function of pressure. Thus, if the air core remains constant, the ratio  $C/\sqrt{p} = K$  should be constant.\* It was found that for a range of pressures the ratio of the capacity to the square root of the pressure,  $C/\sqrt{p}$ , was essentially constant. Values of  $K$  vs.  $d_o$  for various inserts are given in Figure 27. Therefore, the vertical velocity component can also be expressed in terms of the pressure by substituting  $C = K\sqrt{p}$  in Equation (8). However, the true vertical velocity component can be estimated only if the actual area of flow is known. Data on this area and the air core will be reported subsequently. In view of the fact that the air core remains relatively constant for a given nozzle arrangement, the vertical velocity components as reported here differ from the true vertical velocity components by a constant factor. From the observations of Darnell (4a) on transparent plastic nozzles, it appears as though the ratio of the air core diameter to the orifice diameter is of the order of 0.6 to 0.8, except for small orifice diameters, where it is about 0.3. This would mean that the vertical velocity components as computed in this study range from 0.7 to 0.4 of the actual.

Any interpretation of the effect of the vertical velocity component on drop size must take into account the fact that a variation in  $V_e$  also means a variation in capacity for constant orifice diameter. Consequently, if the vertical velocity is increased, the amount of liquid being atomized is increased. A study of the variation in drop size with  $V_e$ , therefore, should properly include the corresponding increase in capacity. This can be done, in one respect, by estimating the so-called atomization efficiency, or the percentage of input power utilized to create additional surface area. The last column of Table 2 shows that as  $V_e$  increased, as a result of higher pressure and capacity, the resulting smaller drop size was attained at a somewhat lower efficiency of energy utilization. Referring to Table 1, a similar decline in efficiency with decreasing drop size occurred as the tangential velocity was increased with pressure at constant capacity. However, at low tangential velocities a decrease in

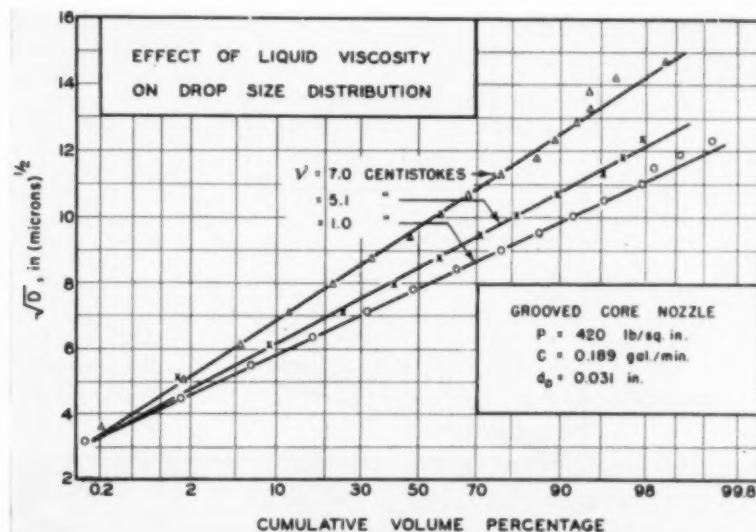


Fig. 24.

\* In the case of liquids of different viscosities the air core will decrease as viscosity increases. For this reason, the capacity of a nozzle increases with viscosity at a given pressure until an air core no longer exists.

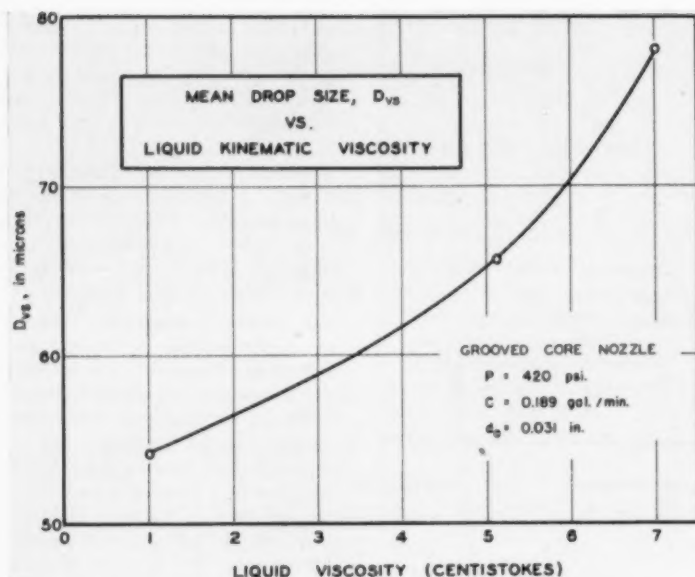


Fig. 25.

$D_{v8}$  was achieved more easily by an increase in  $V_t$  rather than  $V_v$ . It is evident that atomization is accomplished more effectively by imparting a tangential velocity component to the liquid as it leaves the nozzle. In all instances the very low atomization efficiencies should be noted.

Figure 1 illustrates that an unstable liquid film is formed owing to the tangential velocity component. As this film extends outward, it collapses to form drops. Such a mechanism is self-evident, since the outward motion of the liquid not only serves to form unstable conical sheets but also to separate liquid particles from one another. The vertical or axial velocity component, on the other hand, is not so effective in creating unstable configurations, except insofar as internal liquid turbulence causes break-up and air friction tears ligaments from the jet of liquid. The limiting case of

zero tangential velocity at constant vertical velocity resulted in the production of large drops owing to another controlling mechanism of drop formation. This limiting case is indicated by the point corresponding to  $V_t = 0$  in Figure 12.

The action of the tangential velocity component is not unlike the action of the rotational velocity imparted to liquids atomized by spinning disks (2). Adler and Marshall (2) showed in their analysis that for pressures above about 200 lb./sq.in., the cone retreated to the orifice, and break-up appeared to occur at the orifice. For the limiting case of zero vertical velocity, it is evident that good atomization can still be attained in contrast to the limiting case of zero tangential velocity. Thus, the case of zero vertical velocity and finite tangential velocity is essentially the case of spinning disk atomization.

In the determination of the effect of

orifice diameter on drop size, it was necessary to vary two other variables simultaneously. The two selected in this study were the tangential and vertical velocity components at constant pressure. As is evident from the data for  $D_{v8}$  in Table 3, the effect of  $d_0$  at constant pressure was scarcely detectable. The slight effect of  $d_0$  at constant  $V_v$  and  $V_t$  is indicated in Equation (12), which shows that  $D_{v8}$  varies only about 20% over the range of orifice diameters studied. In practice, however, orifice diameter would seldom be varied under such specialized conditions. Pigford and Pyle (23) reported the mass median diameter for commercial spray nozzles to be proportional to the orifice diameter. Longwell (17) reported proportionality between a weight mean diameter and the orifice diameter divided by the sine of one half the cone angle.

Tests on an orifice with rounded edges indicated that slightly smaller droplets and somewhat larger cone angles could be achieved by eliminating sharp edges at the orifice. Irregularities in orifice shape were found to have a pronounced adverse effect on the spatial uniformity of the spray pattern. This is particularly important in the manufacture of nozzles of a given type to ensure duplication of performance. It was also noted that for whirl chamber nozzles, uniformity could be improved by increasing the number of inlets and that the largest cone angles were attained when these inlets were kept tangential with respect to the chamber wall.

The preliminary study of the effect of viscosity indicated that an increase in viscosity produces a rather sharp increase in mean drop size and a decrease in uniformity. This appears reasonable since, in overcoming greater viscous forces, less energy will be available for creation of new surface area for a given power input to the nozzle. In fact, the addition of only slightly more glucose

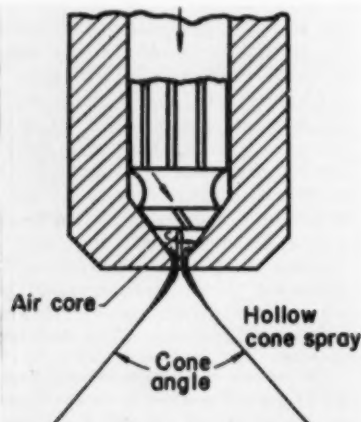


Fig. 26. Sketch of air core developed in grooved-core type nozzle.

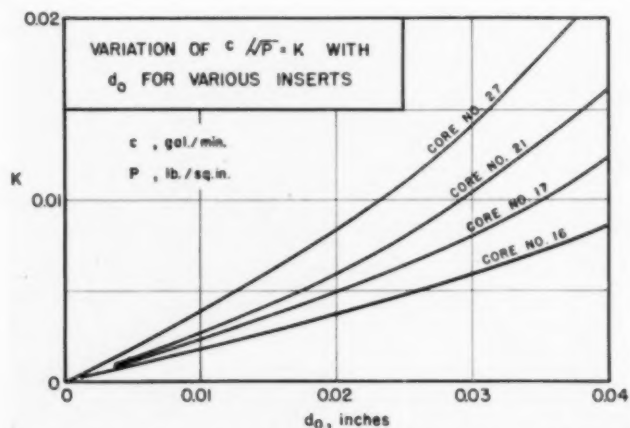


Fig. 27. Discharge coefficients of grooved-core nozzles as a function of nozzle orifice diameter.  $K$  did not vary with pressure up to 1600 lb./sq.in.



to the most viscous solution reported led to ineffective atomization wherein a virtually undisturbed jet of liquid emerged from the orifice. This implied the damping out of any tangential component necessary for atomization, and the reduction of the air core to zero diameter.

Equation (12) gives a method for calculating a mean drop diameter defined as that drop diameter having the same ratio of volume to surface as that for the entire spray. A comparison between the values calculated from Equation (12) and the experimental values is given in the following tabulation:

Run	1	2	3	4	6	7	8	9	10	11	12	13
$D_{VS}$ (calc.)	43.0	54.0	59.5	62.6	63.4	50.	52.6	54.4	55.0	55.	62.2	50.4
$D_{VS}$ (obs.)	43.3	54.3	60.0	63.4	63.1	49.7	54.4	55.0	53.3	52.4	69.9	51.0

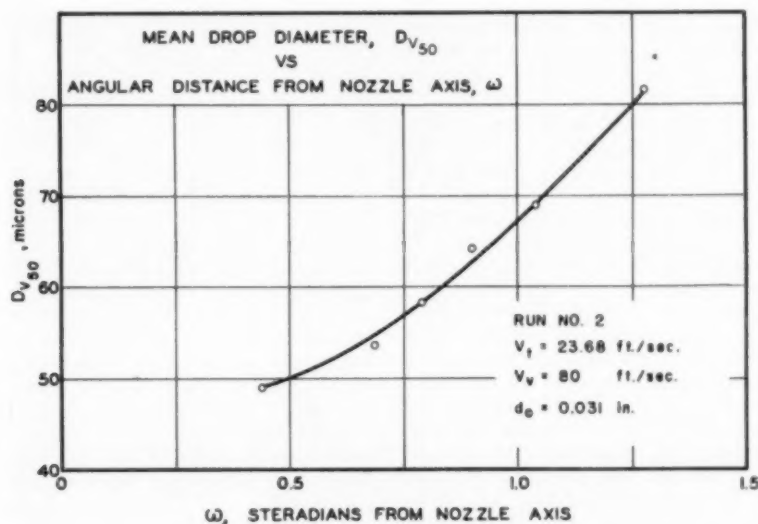


Fig. 28.

The values of  $D_{VS}$  reported in the paper represent average values for the entire spray. However, the average drop size varied with position. A typical variation is shown in Figure 28, where the mass median diameter is plotted as a function of distance, in steradians, from the nozzle axis. It is evident that the larger drops were concentrated near the outside of the spray.

Analysis of the modified Nukiyama-Tanasawa empirical equation [Equation (1)] for estimation of  $D_{VS}$  showed that its applicability to centrifugal pressure nozzles was questionable because it assumes no dependency of  $D_{VS}$  upon  $V_t$  as long as  $V_v$ ,  $d_o$ , and  $p$  are fixed.

Longwell's formula for estimating mean drop diameter from data on viscosity, pressure, orifice size, and cone angle did not fit the data of this study.

In order to illustrate a use for the results of this study, the following example problem is given.

#### EXAMPLE

A centrifugal pressure nozzle operating at 300 lb./sq.in. is delivering a liquid to a small-scale spray drying operation at a rate of 0.25 gal./min. (2 lb./min.).

It is known that the drying system will permit an increase to 0.40 gal./min. What effect will the increased capacity have upon the average drop size and drop size distribution?

#### SOLUTION

The initial conditions of operation are as follows:

$$C_1 = 0.25 \text{ gal./min.}$$

$$p_1 = 300 \text{ lb./sq.in.}$$

For the new condition:

$$D_{VS} = 286(0.04 + 0.17)$$

$$e[13.03/102 - 0.00045 \times 24] = 54.1\mu$$

$$s = (1.51)(1.59)(0.698) = 1.68$$

It is of interest to note that a smaller average drop size would be expected if the higher capacity is attained by virtue of an increase in pressure only. Also, a more uniform spray would be expected.

#### Acknowledgment

The writers wish to acknowledge the financial support of the study by the Shell Fellowship Committee and the Wisconsin Research Foundation. Appreciation is also extended to Professor K. M. Watson and Dr. A. M. Mark for valuable suggestions.

#### Notation

- $A_c$  = cross-sectional area of a single groove in a grooved-core-type nozzle, sq.in.
- $a$  = constant in the Nukiyama-Tanasawa equation for drop-size distribution
- $b$  = constant in the Nukiyama-Tanasawa equation for drop-size distribution
- $C$  = capacity of nozzle, gal./min.
- $D$  = diameter of an individual droplet,  $\mu$
- $D_m$  = drop diameter corresponding to maximum value of  $N$
- $D_{VS}$  = volume median diameter,  $\mu$
- $D_{VS}$  = diameter of a droplet whose ratio of volume to surface area is equal to that of entire spray,  $\mu$
- $d_o$  = orifice diameter, in.; jet diameter, in.
- $f_v(V_v)$  = function relating  $D_{VS}$  to  $V_v$  for constant  $V_t$  and  $d_o$
- $f_v(V_v)$  = function relating  $\theta_m$  to  $V_v$  for constant  $V_t$  and  $d_o$
- $f_v(V_v)$  = function relating  $s$  to  $V_v$  for constant  $V_t$  and  $d_o$
- $g_v(V_v)$  = function relating  $D_{VS}$  to  $V_t$  for constant  $V_v$  and  $d_o$
- $g_v(V_v)$  = function relating  $\theta_m$  to  $V_t$  for constant  $V_v$  and  $d_o$
- $g_v(V_v)$  = function relating  $s$  to  $V_t$  for constant  $V_v$  and  $d_o$
- $H$  = vertical distance between nozzle orifice and sampling apparatus, in.
- $h_v(d_o)$  = function relating  $D_{VS}$  to  $d_o$  for constant  $V_v$  and  $V_t$
- $h_v(d_o)$  = function relating  $\theta_m$  to  $d_o$  for constant  $V_v$  and  $V_t$
- $h_v(d_o)$  = function relating  $s$  to  $d_o$  for constant  $V_v$  and  $V_t$
- $k_L$  = constant in Longwell's equation for median drop size
- $k_L'$  = constant in Longwell's equation for drop-size distribution
- $k_S$  = constant in modified Nukiyama-Tanasawa equation for mean drop size
- $K = C/\sqrt{p}$
- $l$  = linear distance from central nozzle axis, in.
- $M$  = value most frequently observed in a normal probability distribution

$$d_o = 0.04 \text{ in.}$$

$$(V_v)_1 = 63.9 \text{ ft./sec.}$$

$$(V_t)_1 = 15 \text{ ft./sec.}$$

Assuming that the increase in capacity is brought about solely by a change in pressure, one can write

$$p_2 = p_1(C_1/C_2)^2 \text{ or}$$

$$p_2 = 300 \left( \frac{0.40}{0.25} \right)^2 = 770 \text{ lb./sq.in.}$$

For the new condition,

$$(V_v)_2 = 63.9 \times \frac{0.40}{0.25} = 102 \text{ ft./sec.}$$

$$(V_t)_2 = 15 \times \frac{0.40}{0.25} = 24 \text{ ft./sec.}$$

At initial conditions, from Equation (12),

$$D_{VS} = 286(0.04 + 0.17)$$

$$e[13.03/102 - 0.00045 \times 24] = 54.5\mu$$

and from Figures 14 and 15,

$$s = (1.55)(1.73)(0.698) = 1.87$$

$N$  = number of drops  
 $N_i$  = number of drops in  $i$ -th size class  
 $N_g$  = number of grooves in a grooved-core-type nozzle  
 $p$  = nozzle gauge pressure, lb./sq.in.; also constant in the Nukiyama-Tanasawa equation, Equation (2), for drop-size distribution  
 $Q_i$  = volume rate of flow of liquid in an atomizer  
 $q$  = constant in Nukiyama-Tanasawa equation for drop-size distribution  
 $R$  = weight fraction of spray sample above size,  $D$ , in Longwell's equation for drop-size distribution  
 $s$  = standard deviation in a normal probability distribution; also index of uniformity, volume basis  
 $V_t$  = tangential velocity component, ft./sec.  
 $V_t'$  = effective tangential velocity, ft./sec.  
 $V_z$  = vertical velocity component, ft./sec.

#### Greek Symbols

$\alpha$  = angle made by grooves with the horizontal in a grooved-core-type nozzle  
 $\beta$  = angle made by inlets with inner wall of a whirl chamber  
 $\gamma$  = liquid kinematic viscosity, stokes  
 $\theta$  = spray cone angle, degrees  
 $\theta_{80}$  = plane angle subtending 80% of total spray, degrees  
 $\mu$  = liquid viscosity, poise; also denotes micron as unit of measure  
 $\eta_s$  = per cent of input power used to create additional surface area  
 $\rho$  = density of liquid, g./cc.  
 $\sigma$  = surface tension, dynes/cm.  
 $\omega$  = solid cone angle, steradians

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#### Discussion

G. G. Lamb (Northwestern University, Evanston, Ill.): I notice that the equipment developed pressure by means of compressed nitrogen, which presumably would saturate the liquid, and therefore the liquid would have dissolved air in it, which should have an effect on atomization, with marked vaporization.

R. W. Tate (University of Wisconsin, Madison, Wis.): Although we made no investigation concerning this point, there was no observable indication that any peculiar phenomenon was occurring. However, I could not say definitely what effect it would have.

Richard Loster (General Foods Corp., Hoboken, N. J.): I was wondering if you had considered the effect of film thickness of liquid leaving the nozzle?

R. W. Tate: Such an approach might yield fruitful results especially on the basis of photographs we have taken, and I think that we can draw a comparison between that type of film, even though it is in conical form, and the type of film emitting from the periphery of a disk. I think that some of the analytic work which has been applied to the formation of such films could possibly be interpreted for pressure nozzles, also, although our work did not carry on to that point.

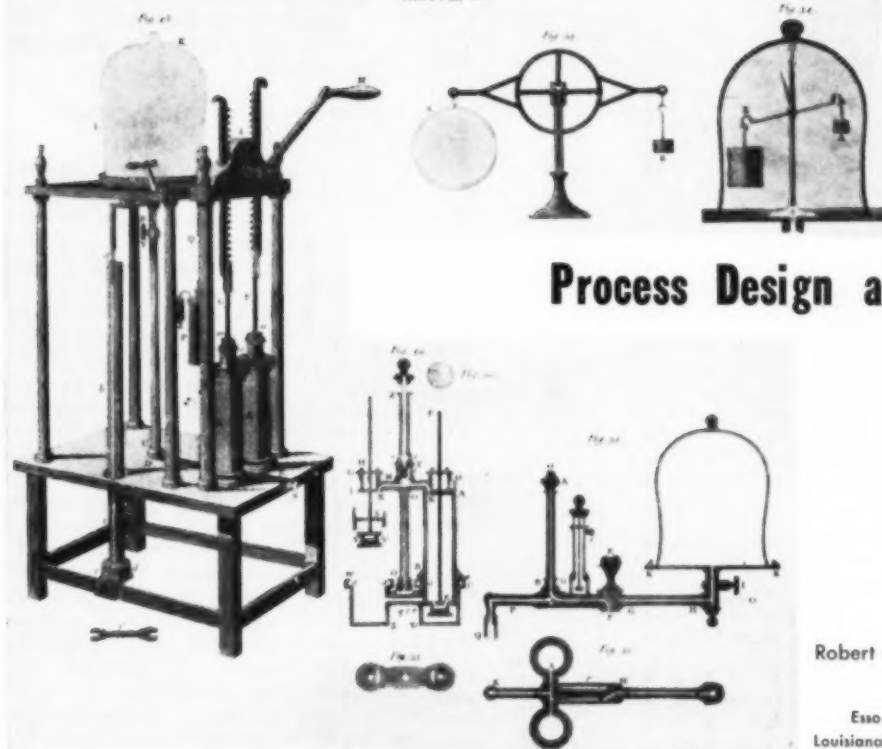
R. S. Bowles (Proctor & Gamble Co., Ivorydale 17, Ohio): Our interest is in droplets or granules in large sizes compared to those with which you worked, and one thing we notice is that practically all your work concerns atomization of mists for Diesel engines, scrubbing, and that sort of thing, involving very fine atomization. On a tonnage basis, at least, we have a very large interest in big drops; I mean 60- to 20-mesh U. S. screen sizes. I know your study didn't include sprays that coarse, but I would like to say that such work would be intensely interesting to us.

R. W. Tate: Our study did stop at modest capacities and operating pressures and would not approach the industrial operation which you have in mind. However, I think it should be pointed out that we are talking about the particles while they are still liquid. In a spray drying operation you would not have the same size droplet in the form of a solid particle as you would in a wet atomized particle just leaving the nozzle. I think, too, that any study relating the nozzle performance characteristics to the properties of dried particles would involve a further study of how the drying of the slurry, or whatever was being atomized, occurs.

L. H. Allen (Foster D. Snell & Co., Inc., New York, N. Y.): If I correctly interpret the papers that have just been presented, there seems to be good indication that low liquid velocities produce improper atomization and, as a result, a wide variation in particle size. As velocity is increased, a point is reached where particle size is relatively constant. At higher velocities, where either the atomizing disk or the single fluid spray nozzle is used, the spread in particle size begins to widen again. Am I correct in that?

R. W. Tate: We observed that, as larger particles were formed, a less uniform spray occurred. I think it is important whether the mechanism is principally atomization by air friction and tearing action or a breakdown of an unstable configuration. I believe that, with pressure nozzles at least, your observation is true for both types. The vertical velocity component is pretty much a measure of atomization by air friction, whereas the tangential velocity would provide a more unstable configuration.

(Presented at A.I.Ch.E. Columbus meeting)



## Process Design and Specification of Pumping Equipment

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The chemical engineering designer is confronted with the necessity of specifying proper pumping equipment perhaps more often than any other single process item with the possible exception of vessels and exchangers. Yet, a standard for the evaluation and specification of design factors, so well defined for vessels and exchangers, is lacking in the case of pumps. A general design procedure together with some description of the factors influencing pump selection and operation is therefore outlined in this article to help satisfy this need. When the procedure given is followed, a concise yet complete specification listing evolves to cover the two main functions of a process specification, namely, to permit:

1. the preparation of an adequate mechanical specification for ordering or the evaluation of equipment already available for possible use in the new or expanded service.
2. the estimation of the cost of the installation.

Although the considerations presented here necessarily reflect those generally applicable at one location, the author believes the principles are fundamental and therefore adaptable throughout the petroleum and chemical industry.

### GENERAL DESIGN FACTORS

Three types of pumps are usually em-

ployed in general chemical service. They are (a) centrifugal, (b) reciprocating, and (c) rotary. Subclassifications of these types are sometimes specified in special cases, i.e., *vertical-well* pumps are a form of centrifugal pump used when low suction head is encountered and *controlled volume* pumps are a form of reciprocating pump used for accurate quantitative injection.



Robert L. Jacks

Robert L. Jacks is a design engineer in the technical division of the Esso Standard Oil Co. (Louisiana division). He received a B.E. degree from Tulane University in 1944 and an M.S. from the Massachusetts Institute of Technology in 1946. Joining the Esso Laboratories of the Standard Oil Development Co. at that time, he worked on polymer development until 1947 and then transferred to Esso's technical organization for operations analysis studies associated with chemicals manufacture. In 1948, he became a design engineer and has since been active on the design problems connected with Esso's operations at Baton Rouge.

Generally speaking, the centrifugal pump is to be preferred for high-capacity, low-head services, whereas the reciprocating type is most desirable for low-capacity, high-head applications. Quantitatively, this is shown in Figure 1. Where the capacity-head relationship falls within the borderline area, the choice is decided by economic and operating considerations. Of course, other factors influence the choice as well as capacity and head (5), a few of these being the fluid viscosity, quantity of undissolved gas, and abrasiveness caused by solids present.

A brief description of the more widely used pump types is presented here. A complete treatment of the subject is given by Church (1).

### CENTRIFUGAL- OR RADIAL-TYPE PUMPS

The centrifugal pump is the most widely used type in petroleum and chemical operations. It is characterized by uniform discharge pressure and is adaptable to changing flow rate requirements, thus lending itself readily to automatic-control systems.

All centrifugal pumps operate on the principle of imparting high velocity to the fluid by centrifugal force and converting this velocity to pressure by expanding the cross section of

Table 1.—Reciprocating Pump Capacities

Pump size*	Maximum piston speed (ft./min.)	Capacity of recommended duplex pump (gal./min. of H <sub>2</sub> O)**	Pump size*	Maximum piston speed (ft./min.)	Capacity of recommended duplex pump (gal./min. of H <sub>2</sub> O)**
2½ × 1½ × 2	30	3.93	12 × 5½ × 12	90	188.8
2½ × 1½ × 2	30	3.93	12 × 6 × 12	90	224.8
3 × 2 × 3	40	11.1	12 × 7 × 13	95	322.8
3 × 2¼ × 4	50	17.6	12 × 7 × 18	110	373.8
3½ × 2¼ × 4	50	26.2	12 × 7½ × 18	110	429.2
3½ × 3½ × 4	50	42.5	12 × 8 × 12	90	399.5
4½ × 2¼ × 4	50	26.2	12 × 8 × 18	110	488.3
4½ × 3 × 4	50	31.2	12 × 10 × 18	110	763.0
4½ × 3 × 6	65	40.6	12 × 12 × 20	115	1148.0
4½ × 5 × 6	65	112.7	12 × 12 × 24	120	1198.5
5¼ × 3½ × 5	60	51.0	14 × 8 × 20	115	510.5
5½ × 4 × 7	70	77.6	14 × 8½ × 20	115	576.3
6 × 2 × 6	65	18.0	14 × 20 × 18	110	3060.0
6 × 4 × 6	65	72.1	15 × 7 × 18	110	373.8
6 × 5½ × 12	90	188.8	15 × 8 × 18	110	488.3
6 × 5¾ × 6	65	149.1	15 × 10½ × 20	115	879.0
6½ × 6 × 12	90	224.8	15 × 10½ × 24	120	917.6
6½ × 4 × 10	80	88.8	16 × 3½ × 12	90	76.5
6½ × 4½ × 8	75	88.5	16 × 8 × 18	110	488.3
7 × ¾ × 10	80	3.1	16 × 10½ × 18	110	841.1
7½ × 2½ × 10	80	34.7	16 × 12 × 24	120	1198.5
7½ × 4½ × 7	70	98.3	16 × 14 × 24	120	1631.4
7½ × 4½ × 10	80	112.4	18 × 6 × 18	110	274.7
7½ × 5 × 6	65	112.7	18 × 8 × 16	105	466.1
7½ × 5 × 10	80	138.7	18 × 8 × 18	110	488.3
7½ × 6 × 10	80	199.8	18 × 8¼ × 24	120	566.5
7½ × 7¼ × 10	80	291.5	18 × 9 × 16	105	589.9
7½ × 7½ × 6	65	253.6	18 × 9 × 18	110	618.1
8 × 6 × 12	90	224.8	18 × 9½ × 18	110	688.5
8 × 6½ × 12	90	263.8	18 × 14 × 24	120	1631.4
8 × 7½ × 12	90	351.1	20 × 5 × 20	115	199.4
8 × 8 × 12	90	399.5	20 × 6 × 12	90	224.6
8 × 9½ × 12	90	563.1	20 × 9 × 15	100	561.9
10 × 4½ × 10	80	112.4	20 × 12 × 12	90	898.9
10 × 6 × 10	80	199.8	20 × 12 × 24	120	1198.5
10 × 6 × 12	90	224.8	21 × 7 × ½ 24	120	468.2
10 × 6½ × 12	90	263.8	22 × 10 × 24	120	832.3
10 × 7 × 12	90	305.8	22 × 12 × 24	120	1198.5
10 × 7½ × 12	90	351.1	22 × 14 × 20	115	1560.0
10 × 8 × 10	80	355.1	24 × 3½ × 24	120	102.0
10 × 8 × 12	90	399.5	24 × 36 × 24	120	10780.0
10 × 8 × 18	110	488.3	36 × 8½ × 24	120	601.4
10 × 10 × 18	110	763.0			
12 × 1¼ × 12	90	9.8			
12 × 2½ × 18	110	47.7			
12 × 4½ × 12	90	126.4			
12 × 4½ × 18	110	154.5			

\* Pump size is given as (stm. cyl. diam.) × (liq. cyl. diam.) × (stroke)

\*\* Gal./min. is for max. recommended speed with 15% slippage and neglecting the size of the piston rod. The normal design speed is about 75% of this figure.

the liquid conduit. The theoretical head developed by a centrifugal pump is thus a function only of the velocity of the fluid, and an impeller operating at a given speed will develop the same head (in feet of fluid flowing) regardless of the specific gravity of the material being handled.

There are several standard types of centrifugal pumps used in the petroleum

and chemical industry. The general-purpose type is the single-stage, single-suction volute type which is good for flows up to 1,500 gal./min. and pressure heads as high as 600 ft. It can readily be used even for volatile or toxic fluids and hot oils. With large capacities and medium head requirements such as those in the range of 2,000-50,000 gal./min. at 200 ft. head, the single-stage, double-

suction volute type is more widely employed. A third pump often used is the multistage volute type which is available in capacities up to 4,000 gal./min. with sufficient stages to develop almost any desired head.

#### RECIPROCATING- OR POSITIVE-DISPLACEMENT-TYPE PUMPS

Until recent years, steam-driven reciprocating pumps were used for practically all pumping services except high-capacity, low-head installations. A large number of these pumps are still in service and new pumps of this type are still sometimes warranted. Two types of reciprocating pumps comprise the majority of positive-displacement units in general use. These are the simplex type, consisting of a single steam cylinder and a single process or fluid cylinder, and the duplex type, consisting of two steam and two process cylinders operating together. Nearly all of these are double-acting (two pumping strokes per cylinder per cycle), an exception being the case of high-pressure service where single-acting units are used. The duplex pump is a rugged and simple machine, has a smoother flow than the simplex, and is dependable in operation. The cost of a duplex pump, per unit of capacity, is less than for the simplex type. The latter, however, does occupy somewhat less space and uses a little less steam.

The factors involved in the capacity-head relationships of a reciprocating pump are its stroke, piston diameters, and maximum recommended piston speed. These pumps, therefore, are referred to usually in terms of these variables. Thus, a 12 × 10 × 18 reciprocating pump is one with a 12-in. diameter steam piston, a 10-in. diameter fluid piston, and an 18-in. stroke length. The maximum recommended piston speed varies from about 30 ft./min. for small-capacity pumps to as high as 120 ft./min. for large-capacity units. A tabulation of various pump sizes vs. capacity is shown in Table 1. Knowing the pressure drop across the steam cylinder, the pressure rise in the fluid cylinder is computed by the relation of

$$(\Delta P)_{\text{fluid}} = \left[ \frac{(\text{steam cyl. diam.})^2}{(\text{fluid cyl. diam.})^2} \right] \times (\text{steam } \Delta P) \times (\text{mech. eff.})$$

where (mech. eff.) is that shown in the table on Figure 5 and is unity at shut-off conditions.

#### ROTARY TYPE (Gear or Screw)

Rotary pumps are positive-displacement units particularly adapted to the pumping of high-viscosity liquids which cannot be pumped satisfactorily with centrifugal pumps. Their combination of smooth discharge characteristics with



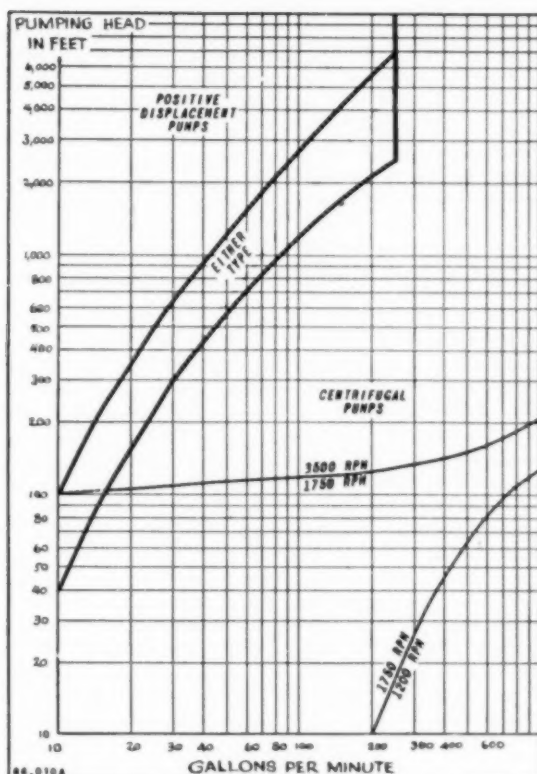


Fig. 1. Pump selection chart.

positive-discharge rate is sometimes desirable. Since their operation is dependent upon close mesh of mechanical parts and small clearances, however, they should never be used where abrasive or dirty fluids are concerned. Where the service is applicable these pumps are available in nearly all combinations of pressure differential and capacity.

#### SPECIAL TYPES

**Vertical-Well Pumps.** Vertical-well-type encased centrifugal pumps are being used more extensively every day. They are designed to provide a self-priming principle for the cases where a pump suction at ground level would not provide sufficient net positive suction head (NPSH) (see design procedure section). These pumps are constructed on a vertical axis with the suction point at the lowest level. They may be installed as a unit sunk into the ground, often with only the motor drive and discharge nozzle above ground.

**Controlled Volume Pumps.** Controlled volume pumps are designed to deliver constant-flow quantities over wide pressure differentials. These pumps are manufactured with capacities as low as a few cubic centimeters an hour and can be used even in large capacity service up to 10 gal./min. where constant flow or injection is mandatory. They are available over these

flow ranges for service up to as high as 20,000 lb./sq.in. gauge. As with any reciprocating plunger or piston-type unit, the capacity is a function of three variables: the area of the plunger face, stroke length, and speed. One or both of the last two are adjustable on controlled volume pump thus allowing wide variation in the quantity pumped. A treatment of the principle of operation, construction, and application of this type of pump has been given by Sheen (4).

#### DESIGN PROCEDURE FOR NEW INSTALLATION

The design of a new pump installation should never be undertaken without first making a schematic picture of the system involved. This picture should include all piping, equipment, controls, and the like from the constant-pressure point on the pump suction to the constant-pressure point on the pump discharge. Once this is drawn, the considerations required to complete the process specification sheet are simplified. The process specification sheet is shown in Table 2. Its function, as mentioned previously, is to facilitate the recording and transfer of the vital process-information items to the mechanical designer, estimator, and pump manufacturer. It also can be referred to as a conclusion sheet since it sets down the results of the process-design calculations. These calculations,

furthermore, can be made with the specification sheet as an outline, thus providing a quick means of file reference to any particular point in the design at a later date.

A number of the specification items listed on the form of Table 2 are self-explanatory, and their values can be found by using one of the many standard-data references available in most engineering libraries. Other items on the form require more effort in their evaluation so that some explanation is justified and is given below:

#### PUMP ITEM NO.

This item serves to identify the unit for reference in all subsequent work and correspondence until actual installation is made. At that time a permanent item number is assigned by the operating division. Since many pumps are specified which are never bought, the item number assigned by the process designer should be selected in such a way as to avoid confusion with item numbers of equipment already in service or on order.

#### SERVICE

The description of the service of the pump should be as brief as possible. Reference to the purpose for which it is to be designed is the function of this item. Hence, such titles as "fractionator feed," "emergency pumpout," or "reactor quench" would be appropriate.

TABLE 2.

#### PROCESS SPECIFICATION FOR PUMPING EQUIPMENT

PROCESS DESIGN	P.T.C.	PLANT	CPLA-2
CHECKED BY	RLJ	SPEC. NO.	MM-000
DATE	3/20/52	ITEM NO.	P-305
GENERAL			
SERVICE	Furnace Feed		
NO. OF PUMPS REQUIRED	IN REGULAR USE	1	
	AS SPARES	1	
PROCESS REQUIREMENTS PER PUMP			
FLUID HANDLED	Gas Oil		
QUALITY OF FLUID	CORROSIVE OR NON-CORROSIVE	Slightly Corrosive	
	CORROSIVE COMPOUNDS	Sulfur	
	SOLIDS (IF ANY)	None	
QUANTITY HANDLED G/PM AT 60°F & 750 MM	10,350		
SPECIFIC GRAVITY AT 60°F & 750 MM	0.862		
PUMPING TEMPERATURE	°F	150	
VISCOSITY-CENTIPOISES AT PUMPING TEMP.	6.5		
SECTION CONDITIONS (AT PUMP)			
PRESSURE	P.S.I. (ABS. OR GA.)	0 psig	
VAP. PRES. AT PUMP TEMP. P.S.I. (ABS. OR GA.)	Negligible		
SP. GR. AT PUMP TEMP. & SECTION PRESS.	0.862		
NET POSITIVE HEAD ABOVE VAP. PRESS. FT.	40.6		
DISCHARGE CONDITIONS (AT PUMP)			
PRESSURE	P.S.I. (ABS. OR GA.)	220 psig	
SP. GR. AT PUMP TEMP. & SECTION PRESS.	0.862		
CAPACITY AT DISCH. COND.	GPM	294	
DRIVER CONDITIONS			
DIFFERENTIAL PRESSURE	P.S.I.	220 psig	
	FT.	602	
LIQUID HORSE POWER	HP	37.7	
MAXIMUM TEMPERATURE	°F	250	
MAX. SECTION PRESS. P.S.I. (ABS. OR GA.)	20 psig		
MAX. ALLOWABLE PUMP DP, P.S.I.	200.2		
REMARKS			
(SPECIAL REQUIREMENTS OF PUMPS OR DRIVERS, ETC.)			
Type of Pump Recommended	Centrifugal		
Type of Driver Recommended			
Regular	Motor		
Spare	Turbine		

## NUMBER OF PUMPS REQUIRED

The determination of the number of pumps required for a given service is a more important design point than is generally believed. Most often, the need for only one regular pump is obvious. Where large capacities are involved, however (in the range of 5,000 gal./min. up) the question of using one, two, or more pumps in parallel sometimes arises and economic factors then determine the best installation. Where a spare is warranted, for instance, it may not be necessary to provide 100% spare capacity and two regular pumps with one spare may be the best installation rather than a single regular unit and spare, both handling twice the throughput of a single unit in the three-pump system. Whenever such a case arises, it is well to examine previous installations before making a decision. The question of whether or not to provide spares also merits consideration. Generally, for intermittent service, a pump is not spared. Wherever shutdown of the regular unit for an extended period would impair the plant operation, a spare is mandatory. Nearly all process pumps are thus spared 100%, whereas most transfer and loading pumps are spared only by common manifolding with other pumps in similar service, or not spared at all.

The use of a common spare for two pumps in separate services should be examined closely before so specifying. The first consideration is contamination effects. If it is necessary to guard against contamination of one stream by the other, common sparing is not advisable. Even where contamination is not a problem, however, careful design of common sparing is required. Thus, for the two services (a) 1,000 gal./min. of a fluid with 0.50 sp. gr. pumped through 100 lb./sq.in.  $\Delta P$  and requiring a 100-hp. driver, and (b) 1,000 gal./min. of a fluid with 0.70 sp. gr. pumped through 70 lb./sq.in.  $\Delta P$  and requiring a 64-hp. driver, the common spare must be rated at 1,000 gal./min. and 140 lb./sq.in.  $\Delta P$ , and a 140-hp. motor is required. The reason for the higher pressure differential and horsepower is that, for centrifugal pumps, the total head does not change when the specific gravity is changed. The required head to be developed by the pump in the first service would have to be 463 ft. whereas, that for the second service is only 231 ft. But when the spare operates, it will always put up 463 ft. at 1,000 gal./min. and 463 ft. on a 0.70 sp. gr. fluid is equivalent to 140 lb./sq.in. Thus, a common spare may not be the best arrangement when specific gravity is taken into consideration. Other factors, of equal importance, are the maximum temperature, viscosity, capacity vs. head characteristics, net positive suction pressure, casing design pressure, corrosive properties of the fluids handled and the type of pump seals. All of these should be checked before specifying a dual-purpose spare.

## FLUID HANDLED

Only a generally descriptive term should be used to identify the fluid handled. It is not necessary to list all of the individual components in a mixture. Thus, such terminology as "butenes,"

"solvent," or "caustic" are better than a detailed listing.

## QUALITY OF FLUID

Information on the quality of the fluid is necessary to determine the materials of construction and internal mechanical design. The effect of corrosive or abrasive elements in the fluid can be injurious to both the pump and to the process. Where corrosion products from certain metals cannot be tolerated in the process, however, this fact should be noted under "special requirements" since the item "corrosiveness of fluid" on the specification sheet refers to corrosion to steel from a mechanical and maintenance standpoint only. Nearly always, the extent of corrosion tolerance of the fluid in question is known from past experience in the plant equipment or can be found from standard corrosion tables (2, 3). However, if a reasonable investigation does not yield a definite answer, "unknown" should be written on the specification sheet opposite "corrosive or non-corrosive" and the pump manufacturer is then consulted for a recommendation. Under no circumstances should the space be left blank or dashes inserted. In reporting any solids present, it is helpful, although not necessarily required, if the approximate per cent by volume and the size of the particles can be given in addition to the name and form of the compound.

## QUANTITY HANDLED

Pumps are designed on the basis of the maximum rather than the normal flow rate to be handled and this maximum is the value reported on the specification sheets. In the absence of specific information, the maximum can be taken as 10% above the normal flow rate for streams to storage and 20% above the normal for streams to operating equipment (reflux, recycle, feed, etc.). For purposes of establishing limiting conditions, the minimum flow is also a necessary design factor although not itself reported on the specification sheet. Generally, it is unsatisfactory to operate a centrifugal pump at less than 20-30% of its rated capacity and pumps developing high heads should not be operated at less than 30-40% of rated capacity. Otherwise, such undesirable effects as overheating and seizure may occur. For wide ranges of flow, this may mean provision of circulation lines around the pump to obtain satisfactory operation.

## SUCTION CONDITIONS AT PUMP

**Pressure.** The suction pressure is evaluated by subtracting the maximum line and equipment friction pressure drops in the suction system from the upstream pressure at the point of constant-pressure level such as a drum or tower. The difference in the elevation of the liquid at the upstream point of constant pressure and the center line of the pump suction also should be taken into account. Suction pressure is usually reported as pounds per square inch gauge unless partial vacuum necessitates absolute units. Suction lines should be designed for low friction losses in most cases and for this reason they are

usually a size or two larger than the discharge lines. For evaluation of pressure drops, the same considerations apply as are described under Discharge Conditions.

**Vapor Pressure.** The vapor pressure of the fluid being pumped is determined at the pump-suction temperature for calculation of the net positive suction head. In the case of a material withdrawn at its boiling point from a tower or vessel, the tower or vessel pressure is taken as the vapor pressure of the material.

**NPSH.** The net positive suction head above vapor pressure is the difference between the absolute suction pressure and the vapor pressure at the pump suction temperature. There are many pumps purchased with NPSH requirements as low as 6-8 ft. for horizontal centrifugal pumps and down to 1 ft. for vertical centrifugal pumps. However, such requirements call for special pump design and are therefore more expensive. Wherever possible, therefore, the NPSH should be 10 ft. or more for capacities up to 500 gal./min. and 20 ft. or more for capacities above 500 gal./min. This is especially true if loss of suction on the pump will upset the operating conditions in the plant, and consideration should be given to possible variations in the vapor pressure of the pumped material if the NPSH is near the minimum. Taylor (5) has given a discussion of the NPSH problem which outlines possible solutions for low NPSH conditions. (It is also good practice to specify 25-ft. maximum NPSH for pumps which have no such problems. In doing so, the pump is more adaptable to higher throughputs without NPSH limitations and may be used more readily in other services.)

## DISCHARGE CONDITIONS AT PUMP

**Pressure.** The discharge pressure is evaluated by adding the maximum line and equipment pressure drops in the discharge system to the downstream pressure at the point of constant-pressure level, again taking into account static head. The pressure is reported in the same units as the suction pressure. In the evaluation of the pressure drops, the following rules apply:

- Friction losses through lines and exchangers at normal flow are usually increased by the ratio of maximum to normal flow squared. Thus, the  $\Delta P$  for a maximum flow 20% above normal is  $(1.20)^2 \times 100 = 144\%$  of the normal  $\Delta P$ .
- The pressure drop through a control valve must be calculated at maximum flow. The pump and valve designs should be coordinated to obtain the greatest efficiency commensurate with good control. In the absence of any data on the valve, a rough estimate of the  $\Delta P$  can be made by assuming  $\Delta P = 20\%$  of the friction loss in the system plus 10% of the static head against which the system operates.
- The permanent loss through an orifice is taken as 3 lb./sq.in. which corresponds to a 100-in.-range tube—the most common type employed on meters.
- For purposes of calculating potential head caused by differences in elevation, the suction

and discharge parts of all pumps are figured to be 3 ft. above the level of the ground (or the supporting platform).

#### DESIGN CONDITIONS

**Differential Pressure.** The differential pressure in pounds per square inch is obtained directly by subtracting the suction pressure from the discharge pressure. This value is then converted to "feet of fluid flowing" by multiplying by the factor of (2.31/sp. gr. at discharge conditions).

**Liquid Horsepower.** The liquid horsepower is the output horsepower of the pump and is not to be confused with brake horsepower. Liquid horsepower is computed as

$$\text{liquid hp.} = \frac{(\text{gal./min.})(\text{lb./sq.in.})}{1715}$$

**Maximum Temperature.** The design temperature is usually specified as 50° F. higher than the maximum stream temperature. All possibilities should be considered in arriving at a value, such as the use of the pump as spare for a higher temperature stream.

**Maximum Suction Pressure.** The maximum suction pressure on the pump is dictated by such factors upstream of the pump as safety valve settings, hydrostatic head, and maximum discharge pressure of other pumps. Each case must therefore be carefully analyzed before reporting this value.

**Shut-Off Pressure.** While it is rarely necessary to report the shut-off pressure of a pump to the mechanical designer, it is good practice for the process designer to include the approximate value to be expected in his design calculations. For centrifugal pumps, it may be estimated as maximum suction pressure plus 120% of the design pump head differential. For reciprocating pumps, unless the discharge is protected by a safety valve set for a lower value, it is

$$(\text{max. suct. pressure}) + \left[ \frac{(\text{steam cyl. diameter})^2}{(\text{fluid cyl. diameter})^2} \right] \times (\text{max. steam } \Delta P)$$

**Maximum Allowable  $\Delta P$  Across the Pump.** The casing design pressure of any downstream equipment is generally dictated by the maximum suction pressure on the pump plus a maximum allowable pressure rise through the pump. Pumps specified to the manufacturer only in terms of normal  $\Delta P$  and maximum suction pressure may result in the design head vs. capacity point being well down on a sharply rising curve. So that downstream equipment can be properly designed or protected for pressure, the maximum allowable pressure rise in the pump (i.e., the limit to which the head vs. capacity curve will rise) should be specified.

**Special Requirements.** Many considerations of a special nature should be investigated by the process designer and reported on the specification sheet. Included in this category are the kind of pump and the type of driver recommended. (When a reciprocating pump is desired, it can be sized by use of the run-around chart shown in Fig. 3.) For reciprocating pumps, steam is nearly always the driving medium (some air-driven installations are used), and in this

case, the steam suction and exhaust pressures should be supplied. In the case of centrifugal pumps, the driver is most often an electric motor. When specifying motor drivers, the mechanical designer should be told whether it is necessary to have explosion-proof units as this materially affects the cost. In all areas where the possibility exists of having explosive mixtures present, explosion-proof motors are usually specified. Turbine drivers for centrifugal pumps are also advantageous in particular cases. Both economic and dependability factors may influence the choice. Thus, for the case where the exhaust steam requirements of an area require throttling of high-pressure steam, it is obviously more economical to do so through a pump turbine than through a control valve. Also, spares for emergency pumps are often steam-driven to assure their operation even when a power failure occurs and the same principle applies to process units where the shutdown of a pump caused by lack of power would seriously jeopardize the plant. Other considerations of a special nature include:

1. Particular location desired.
2. Nozzle locations in certain positions only.
3. Zero contamination or zero leakage desired.
4. Type of impeller preferred (open, closed, or partly enclosed).
5. Pump speed (where an existing motor is available).
6. Type of seal (conventional seals with packing, mechanical seals, and seal oil injection systems).

#### USE OF EXISTING PUMPS

The job of the process designer is not always designing an entire new installation. Quite often it is one of fitting existing equipment to new services. In these cases, several factors must be taken into account that are not involved when specifying new equipment. Nearly always, individual judgment must be used for each case, but many considerations are basic. These considerations are discussed in the following paragraphs.

Even when designing to use an existing pump, the calculations outlined previously should be made just as if a new installation is involved. These then can be altered as desired in accordance with what existing equipment is available. Thus, it is sometimes more economical to increase a pipe size and allow the use of an existing pump of slightly lower head than to purchase a new pump and driver for the existing piping system. In making the calculations for a service handling highly viscous materials (viscosity greater than 20 centistokes) correction factors must be used. Figure 2 illustrates the approximate correction factors which apply at peak efficiency conditions. These factors can be used for rough design but since the corrections are a function of both capacity and head, firm designs should make use of the charts published by the Hydraulic Institute (6).

When use of an existing centrifugal pump in a new service is considered, it is essential that the performance (head vs. capacity) curve for that pump be known. Performance curves should be supplied by the manufacturer for every pump at the time of purchase. If performance curves are not available, then a test on the pump should be run to determine its rating. (These pump tests are also advisable on pumps which have been idle even when the original purchase curves are available to insure there has been no change in impeller size.) Since the performance characteristics of centrifugal-type pumps vary greatly, it is dangerous to make generalizations or assumptions.

If comparison of the required head and capacity with the performance curves indicates the pump to be satisfactory, then the impeller diameter should be ascertained to make sure it has not been changed since the pump was purchased. This is an important point for the process designer to remember since, nearly always, the pump capacity-head characteristics can be altered, sometimes as much as  $\pm 25\%$ , by the mere expedient of changing the impeller size. Although the manufacturer should always be consulted before specifying a change in impeller size, the following relationships can be used to estimate the effects:

- a. The head-capacity curve of a pump with a given diameter impeller can be converted to that for a new impeller size by moving several points on the curve horizontally (capacity scale) an amount proportional to the ratio of impeller diameters and vertically (head scale) an amount proportional to the square of this ratio; and constructing a new curve through these points.

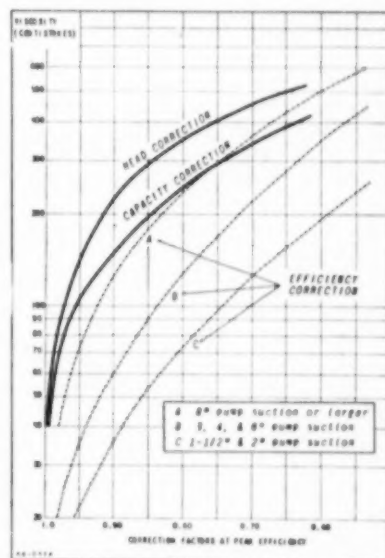


Fig. 2. Centrifugal pump viscosity correction factors.

- b. The brake-horsepower curve is altered by moving it horizontally an amount proportional to the ratio of impeller diameters and vertically an amount proportional to the cube of this ratio.
- c. The efficiency curve will move horizontally only and will shift an amount which aligns it with the new capacity points.

Another method of altering the pump characteristics is to change the rotational speed. While the speed of a motor-driven pump is sometimes changed by installing a new driver, the speeds, ( $n$ ), are normally fixed at 3,500, 1,750, 1,200, and 900 rev./min., and this method of altering pump performance finds widest application with turbine-driven units. (By use of gears, variable-speed motor drives are sometimes used.) A number of useful relations are available to approximate the effects of changes in speed. They are as follows:

- A. Capacity .....  $(Q_1/Q_2) = (n_1/n_2)$   
 B. Head .....  $(H_1/H_2) = (n_1/n_2)^2$   
 C. Brake horsepower .....  $(BHP_1/BHP_2) = (n_1/n_2)^3$   
 D. Efficiency ..... unaffected by impeller speed (the efficiency curve, however, will shift an amount necessary to align it with the new capacity curve)

Keeping these effects in mind, it is well to check the rotational speed rating whenever a new or relocated motor is fitted to an existing pump installation.

Much wider variations of capacity and head are available with reciprocating pumps than for centrifugals. These pumps are, however, limited by (a) maximum pressure caused by mechanical construction, and (b) maximum and minimum recommended piston speed. For the first of these limitations, the original purchase specifications must be consulted. The second limitation can be determined by reference to Figure 3. Any piston speed vs. stroke at lower than basic speed that cannot be plotted within the ranges covered in Figure 3 should never be used, and piston speeds

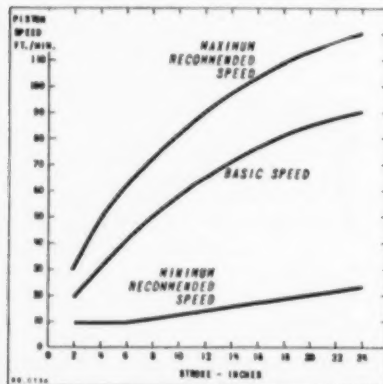


Fig. 3. Reciprocating pump speed ranges.

greater than 125% of the basic speed rating in Figure 3 should be employed only with care. Within these limits the pressure differential across a reciprocating pump can be altered to any desired level by changing the steam pressure drop in accordance with the relation given above under the general design factors for reciprocating pumps. The capacity can be altered in direct proportion to the piston speed.

## SAMPLE DESIGN CALCULATIONS

### EXAMPLE 1

**STATEMENT OF PROBLEM (PROCESS HYPOTHETICAL).** A gas oil feed (28.5° API) is to be pumped from tankage into a cracking furnace in accordance with Figure 4. A pump is to be designed for process service and continuous operation handling 8725 bbl./day (@ 60° F.) of the feed stock from storage at atmospheric pressure. The following design results are available from other equipment calculations:

- Optimum suction line diameter = 8 in.  
 Optimum discharge line diameter = 4 in.  
 Pressure drop in suction line for normal flow = 0.14 lb./sq.in.  
 Pressure drop in discharge line (piping only) for normal flow = 34 lb./sq.in.  
 Pressure drop in exchanger for normal flow = 12 lb./sq.in.  
 Pressure value at control point on exchanger discharge = 125 lb./sq.in. gauge  
 Pressure control on pump suction equipment = atm. vent on tank  
 Temperature maintained in storage tank = 150° F.

**DESIGN CALCULATIONS.** The sketch of the installation is shown in Figure 4 and the resultant pump specification is given in Table 2. Most of the values and specifications reported on the specification sheet in Table 2 are self-explanatory. However, some require explanation as follows:

**Corrosiveness.** This pump is to be in service in a petroleum refinery where the crude fractions contain sulfur. The sulfur content of the gas oil stream to the cracking unit was determined

to be in the range of 0.5 wt. %, a concentration expected to impart slight corrosiveness to the fluid and calling for light alloy steel.

Gallons/hr. (@ 60° F. & 760 mm. Hg. The maximum flow is assumed to be 20% greater than normal. Hence:

$$\text{Max. gal./hr.} = 1.20(8725)(42/24) = 18,350 \text{ gal./hr.}$$

The minimum flow is taken as 75% of the normal, or

$$\text{Min. gal./hr.} = (0.75/1.20)(18,350) = 11,500 \text{ gal./hr.}$$

**Suction Pressure.** The minimum suction pressure on the pump will result from a low level in the tank. Neglecting the difference in elevation between the outlet nozzle of the tank and the suction of the pump (a usual assumption unless the NPSH is near the minimum), the pump suction pressure at minimum tank level is:

$$(0 \text{ lb./sq.in. gauge tank pressure}) - (0.20 \text{ lb./sq.in. } \Delta P \text{ in suction line})$$

$$\text{where } 0.20 = (1.20)^2 \times 0.14 \text{ lb./sq.in.}$$

This value is so close to atmospheric pressure, the latter is reported.

**NPSH.** The net positive suction head is the difference in suction pressure and the vapor pressure, or 14.7 lb./sq.in. Using the specific gravity at 150° F. of 0.840, this is converted to feet as follows:

$$\text{NPSH} = 14.7 \left( \frac{2.31}{0.840} \right) = 40.4 \text{ ft. of fluid flowing}$$

**Discharge Pressure.** This value is found as follows:

Pressure value at point of constant control ..... 125 lb./sq.in.

$$\Delta P \text{ due to potential head} = (20 - 3) \left[ \frac{(0.780 \times 62.4)}{144} \right] = 6 \text{ lb./sq.in.}$$

$$\Delta P \text{ in lines at max. flow} = (34 \text{ lb./sq.in.})(1.20)^2 = 49 \text{ lb./sq.in.}$$

$$\Delta P \text{ in exchanger at max. flow} = (12 \text{ lb./sq.in.})(1.20)^2 = 17 \text{ lb./sq.in.}$$

$$\Delta P \text{ in orifice of flow meter} = 3 \text{ lb./sq.in.}$$

$$\Delta P \text{ in control valve, PRCV} = \Delta P_1$$

$$\therefore \text{Total pressure required} = (200 + \Delta P_1)$$

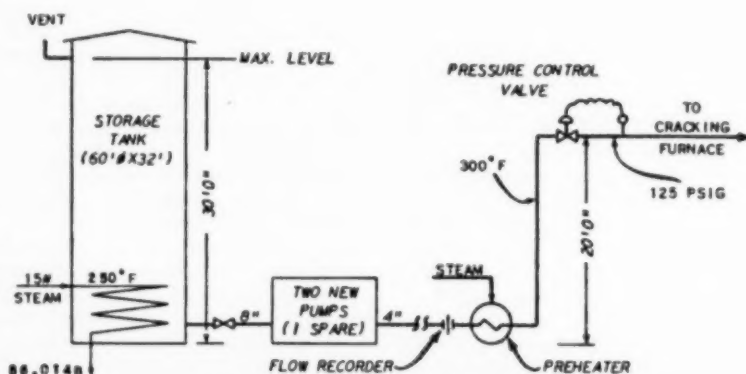


Fig. 4. Simplified flow plan for pump design.



For the control valve, the following rough calculation is made.

line size = 4 in.  
 $\text{gal./min.}_{\text{max.}} = (18350/60) = 306$ ;  
 system  $\Delta P_{\text{max.}} = 69 \text{ lb./sq.in.}$   
 $\text{gal./min.}_{\text{norm.}} = 306/1.20 = 255$ ;  
 system  $\Delta P_{\text{max.}} = 49 \text{ lb./sq.in.}$   
 $\text{gal./min.}_{\text{min.}} = 0.75(255) = 191$ ;  
 system  $\Delta P_{\text{max.}} = 29 \text{ lb./sq.in.}$   
 $\text{sp.gr. @ } 300^\circ \text{ F.} = 0.78 \text{ (approx.)}$   
 back pressure @ 0 flow =  $125 + 6$   
 =  $131 \text{ lb./sq.in.}$

Taking a pump discharge pressure of 220 lb./sq.in. gauge, the valve pressure drops will be  $(220-131) = 89 \text{ lb./sq.in.}$  minus the system pressure drops; or 20.0, 40.0, and 60.0 lb./sq.in. for maximum, normal, and minimum flows, respectively. A 3-in. control valve will pass 400 gal./min. wide open at 20.0 lb./sq.in.  $\Delta P$ . Therefore,  $(306/400) \times 100 = 76.5\%$  of the maximum port area of a 3-in. valve is required for passing the maximum flow.

A wide open 3-in. valve will pass 570 gal./min. at 40.0 lb./sq.in.  $\Delta P$ . Therefore, it will pass 255 gal./min. at the same  $\Delta P$  with  $(255/570) \times 100 = 45.0\%$  of its port area open.

A wide open 3-in. valve will pass 700 gal./min. at 60.0 lb./sq.in.  $\Delta P$ . Therefore, it will pass 191 gal./min. at  $(191/700) \times 100 = 27.3\%$  open.

This design is satisfactory from a control standpoint since the valve is less than 80% open at maximum flow, between 40 and 60% open at

normal flow and greater than 20% open at minimum flow.

The discharge pressure required is thus 220 lb./sq.in. gauge.

**Capacity at Discharge Conditions.** This quantity is calculated from the value reported at suction conditions converted to gallons per minute at 0.840 sp. gr. as follows:

$$\text{gal./min.} = (18,350/60)(0.840/0.882) = 294$$

**Design Temperature.** The design temperature is usually reported as  $50^\circ \text{ F.}$  above the maximum value expected in normal operation. The case in question illustrates an exception to this rule and points out the necessity for examination of all the facts. The normal rule would call for a design temperature of only  $(150 + 50)$  at  $200^\circ \text{ F.}$  In this case, however, the tank steam coil illustration must be examined. Low pressure steam (15 lb./sq.in. gauge) is used for heating, the condensing temperature of which is  $250^\circ \text{ F.}$  Allowing for a  $\Delta T$  drop across the coil of about  $50^\circ \text{ F.}$ , the maximum expected suction temperature at the pump is thus  $200^\circ \text{ F.}$  and the design maximum is  $200 + 50 = 250^\circ \text{ F.}$

**Maximum Suction Pressure.** The maximum suction pressure on the pump will occur when the tank upstream is full and there is no flow. Since the tank is vented at the top and the maximum liquid level is 30 ft. above grade, the pressure at the pump under these conditions (pump suction 3 ft. above grade) is

$$(30 - 3) \times \left[ \frac{(0.840)}{(2.31)} \right] + 14.7 = 24.5 \text{ lb./sq.in.abs.}$$

Shut-off pressure is  $24.5 + 1.20(220) = 288 \text{ lb./sq.in.abs. (793 ft.)}$

**Maximum Allowable  $\Delta P$ .** The downstream equipment is good to 300 lb./sq.in. gauge. The maximum allowable  $\Delta P$  across the pump is thus  $(300 + 14.7) - 24.5 = 290.2 \text{ lb./sq.in.}$

**Special Requirements.** The requirement of smooth pressure control downstream of these pumps calls for centrifugal type units. Since the flow must be maintained during a power failure, the regular should be motor driven and the spare turbine driven.

## EXAMPLE 2

**STATEMENT OF PROBLEM (PROCESS HYPOTHETICAL).** A  $10 \times 7\frac{1}{2} \times 12$  duplex reciprocating pump formerly operating at a piston speed of 65 ft./min. will be available for the service of Example 1 together with a steam source (a 180 lb./sq.in. gauge). Assuming that the smooth-pressure requirement downstream is relaxed and that the pump is mechanically capable of withstanding the maximum calculated discharge pressure, will this pump be satisfactory?

Instructions for use of Fig. 5

1. Select piston speed, stroke, and mechanical efficiency from tables.
2. Determine liquid cylinder diam. from graph.
3. On run around chart, select proper steam cylinder, diameter.

### Mechanical Efficiency

#### Differential Pressure

Stroke in.	to 300 lb./sq.in.		Above 300 lb./sq.in.
	Piston pattern	Packed plunger	Packed plunger
3	55	50	41
4	60	55	44
6	65	60	51
8	68	65	54
10	72	68	57
12	74	70	59
16	76	73	63
18	78	75	65
20	79	77	66
24	80	78	67

Use 90% of above if viscosity exceeds 4,000 SSU

### Basic Piston Speed (ft./min.)

#### Simplex Steam Pump

Stroke in.	Water or cold light oil	Oil over 300° F. or volatile liquids
	oil	liquids
3	30	16
4	33	21
6	42	28
8	50	33
10	58	40
12	65	45
16	73	52
18	80	58
20	85	62
24	90	68

### Speed Correction Factors

	Factor
Duplex Steam	0.90
Simplex Power	1.20
Duplex Power	1.40
Vertical Triplex	1.40

### Viscosity—SSU

500 to 1000 SSU	0.90
1000 to 2000	0.80
2000 to 3000	0.75
3000 to 4000	0.70
4000 to 5000	0.66
5000 to 6000	0.63
6000 to 7000	0.59
7000 to 8000	0.55
8000 to 9000	0.52
9000 to 10000	0.50

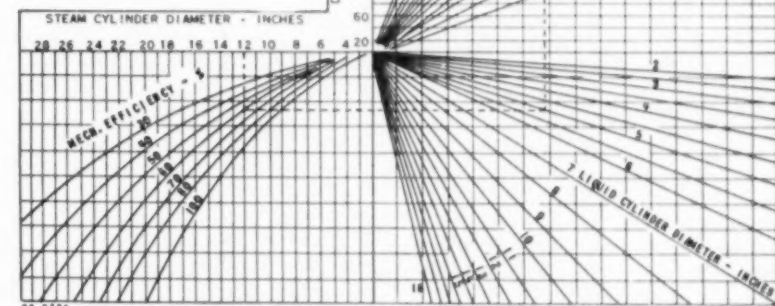


Fig. 5. Reciprocating pump selection chart.

## DESIGN CALCULATIONS

1. The calculations of Example 1 are made exactly as before.
2. From the graph and tables of Figure 5, a  $10 \times 7\frac{1}{2} \times 12$  duplex unit will pump 270 gal./min. with a piston speed of 65 ft./min. This can also be obtained as follows:

piston volumetric output per stroke (one direction) =

$$0.786 \left[ \frac{(7.5)^2(12)}{(12)^2(12)} \right] (7.48) = 2.30 \text{ gal.}$$

$$\text{strokes/min.} = 2(65)/(12/12) = 130$$

gallons per minute allowing for 10% slippage =  $2.30(130)/(0.90) = 270 \text{ gal./min.}$

3. For the requirement of 305 gal./min., the piston speed must be

$$\frac{(305)}{(270)} (65) = 73.5 \text{ ft./min.}$$

This value is below the maximum of 90 ft./min. recommended in Figure 3 for this size pump. This requirement is therefore satisfied.

4. From the table on Figure 5, for a packed plunger-type pump with 200 lb./sq.in.  $\Delta P$  and 12-in. stroke, the efficiency is 70%.
5. From the runaround chart on Figure 5, the steam cylinder diameter needed for the conditions of 205 lb./sq.in. liquid  $\Delta P$ , 180 lb./sq.in. steam  $\Delta P$ , liquid cylinder diameter of 7½ in., and 70% efficiency is 9.5 in. Hence 10 in. is satisfactory.
6. The maximum discharge pressure of the pump is as follows:

maximum discharge pressure = maximum suction pressure +

$$\left[ \frac{(\text{steam cylinder diameter})^2}{(\text{fluid cylinder diameter})^2} \right] \Delta P$$

$$\times (\text{steam } \Delta P) = 24.5 + \left[ \frac{(10)^2}{(7.5)^2} \right] \Delta P$$

$$\times 180 = 355 \text{ lb./sq.in. abs.} \\ = 340 \text{ lb./sq.in. gauge}$$

This is the pressure the equipment downstream of the pump must be able to withstand. Since the downstream equipment is only good for 300 lb./sq.in. gauge, a 300-lb./sq.in. gauge safety valve should be installed on the pump discharge.

7. The  $10 \times 7\frac{1}{2} \times 12$ -in. pump will be satisfactory. (Use of this pump will, however, require another system for controlling the circuit different from that illustrated for service with the centrifugal pump.)

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## Acknowledgment

The author wishes to give credit to the Standard Oil Development Co. from whose reports Table 2, and Figures 2 and 5 were taken, and also appreciation to those whose review and comment have contributed to the accuracy and value of this report.

## Discussion

L. B. Trenholme (Carbide & Carbon Chemicals Co., LaMarque, Tex.): We have similar forms, somewhat more involved, for specifying process pumps and we feel strongly that the materials of construction should be included in the specification sheet filled out by the process engineer. We feel that the engineer should be thoroughly familiar with the liquids that the pump is to handle and consequently should be able to specify the materials of construction better than anyone else.

R. L. Jacks: That question can best be resolved by pointing out that the form presented here covers process design only. A number of mechanical design features are also important but are outside the scope of this presentation. At Esso, the chemical or process engineer does not specify materials of construction unless they affect the process. We, instead, specify the fluid and its corrosiveness. Our mechanical engineers and metallurgists then prepare a mechanical specification for ordering which includes the information Mr. Trenholme spoke of. I believe this is the procedure followed by most large concerns.

In the smaller companies, the process engineer may also do the ordering. If he is not familiar with mechanical design methods, he can still use the process form and enlist the aid of the pump manufacturer in obtaining the best pump. I believe the suppliers will bear me out on this point. They have had considerable experience in matching materials to particular fluids and conditions. Where special fluids are involved, of course, I agree with Mr. Trenholme that they must be identified or the construction material should be specified.

R. T. Sheen (Milton Roy Co., Philadelphia 18, Pa.): My remarks will be made from the standpoint of the pump manufacturer.

Emphasis must be given to one point made by the previous discussor, namely, the necessity for specification of the desired materials of construction. The manufacturer needs help from the customer on this important item. Either the desired materials of construction should be specified, or the chemical to be handled should be specified with all its characteristics. Many customers hold their process as secret indeed and will divulge nothing about their processes, what they are going to handle, etc., and in many cases their specifications for equipment suffer as a result. In spite of

the fact that most equipment manufacturers have excellent engineering staffs, they often are left wondering exactly what a customer has in mind and what to offer for the particular application.

Suggested materials of construction should not be limited to the casing of the pump but should include ideas from customers on the type of seal desired or type of packing required. This additional specification is well worth while as an aid in assuring long and successful life of the pumping equipment once it has been placed in service.

R. L. Jacks: I did not mean to imply in my previous statement that you should not specify to the manufacturer everything you can in the way of materials of construction. The designer should definitely identify the fluid to the manufacturer if he does not give the materials of construction.

W. E. Pratt (Worthington Corp., Harrison, N. J.): In connection with design specifications for a centrifugal pump installation, where a certain type of a standard chemical pump has proved satisfactory and a money-saver in an existing service, what procedure is adopted when an additional similar pump is desired?

We recently received an order for a Worthite chemical pump calling for certain features other than those in our standard pump, which was giving highly satisfactory performance in the same service. To fulfill the order as received would have required a specially built pump, more costly than our standard, and it would have involved a long delivery.

It was suspected that the specifications were taken from a standard form used for refinery pumps, involving features and requirements not included in standard special-alloy acid pumps. Inquiry developed that this was the case and that our standard pump was actually wanted by the operating department to duplicate pumps in service. The order was changed to the standard pump at a much lower price. Quick shipment was made and parts will be available if emergency repairs are required at a later date.

Our suggestion is that costly routine handling of pump specifications by the mechanical design and materials departments can sometimes be avoided by first determining, from the construction and maintenance or operating departments, if a duplicate of a standard pump that is already giving satisfactory performance in similar service is actually wanted.

R. L. Jacks: The designer fell down in that instance. He might have eliminated this trouble if he had also specified that a similar pump was already in service or had he compared the new specification to those put out by the manufacturers for their standard pumps. Both of these procedures are good design practice.

(Presented at A.I.Ch.E. Forty-fifth Annual Meeting, Cleveland, Ohio.)

# Characteristics of a Podbielniak Centrifugal Extractor

Norman Barson and G. H. Beyer Iowa State College, Ames, Iowa

Liquid-liquid countercurrent extraction in a rotor spinning at 5000 rev./min. was studied. Inside the 18-in. diam. rotor were eighteen concentric cylinders slotted at  $180^\circ$  intervals. Light liquid introduced at the periphery of the rotor was displaced inward by heavy liquid flowing outward from the axis. In passing through the rotor both phases formed new interfacial area at which extraction could take place. Density differences between the phases were accentuated by the centrifugal force field, speeding up separation of phases and permitting combined flow rates up to 7 gal./hr. with contact times of only a few seconds.

Using the system boric acid - isoamyl alcohol - water, runs were made extracting boric acid from alcohol into water, and from water into alcohol. Operation with clear effluent streams was possible over a range of light-liquid-exit pressures, corresponding to varying amounts of light-liquid holdup in the rotor. Extraction results were expressed in terms of equilibrium stages, obtained by an analytical solution of the McCabe-Thiele method. The number of equilibrium stages increased with an increase in the ratio of the light-liquid flow rate to the heavy-liquid flow rate, and decreased with a decrease in the speed of rotation. The maximum number of stages, between seven and eight, was realized when extracting from alcohol into water with a minimum holdup of alcohol in the rotor.

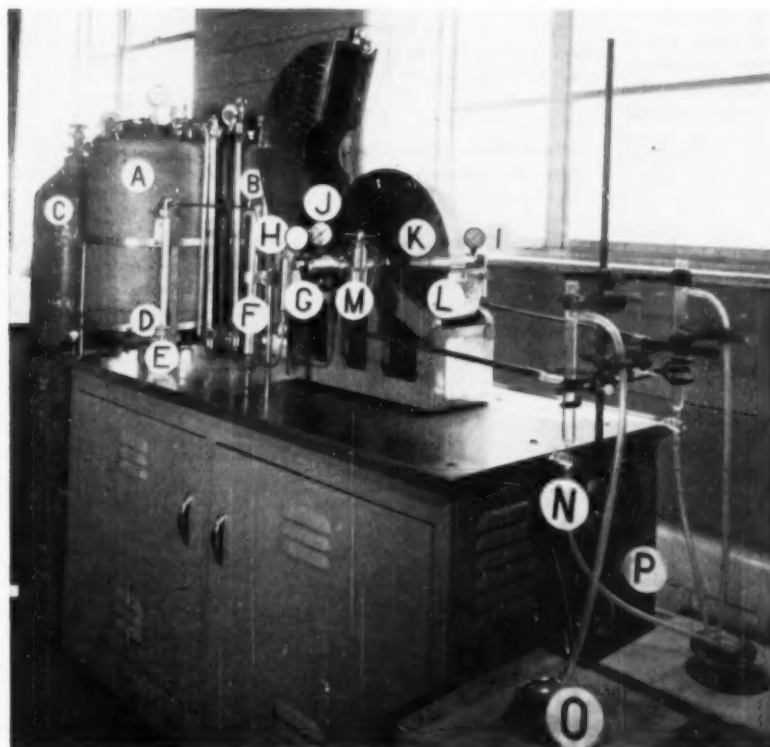


Fig. 1. Photograph of Podbielniak centrifugal extractor.

The principle on which most liquid-liquid extractors operate is the creation of a large interfacial area across which extraction may take place. Packed columns utilize packing with a high surface area per unit volume over which one liquid may flow in a film through another continuous phase. In mixer-settlers, as the name indicates, the two phases are alternately mixed and then allowed to separate. Morello and Poffenberger (13) give an extensive review of commercially available extraction equipment.

In 1934 both Podbielniak (16-22) and Coutor (5, 8) applied centrifugal force to liquid-liquid extraction. The original apparatus of Podbielniak consisted of a rotor mounted on a horizontal axis, containing a perforated spiral through which the two liquids passed countercurrently. That of Coutor was a vertical apparatus which operated like a cream separator, but with intermediate remixing. Other centrifugal devices were developed or patented in 1939 by Thayer (25), in 1940 by Sheldon and Fahnestock (24), and in 1948 by Hertzberg (10). The most recent commercial apparatus is the Luwesta extractor (6), a three-stage extractor based on the Coutor design.

The Podbielniak extractor is described in some detail by Von Berg and Weigandt (27), Brown (2), Elgin (7), and Treybal (26). Its first commercial application was in the pharmaceutical industry where the extraction of antibiotics required a short contact time (1, 3, 11, 15), but in recent years its field has widened to include chemical and refinery applications. Because commercial application of the Podbielniak centrifugal extractor is relatively new, performance data and an analysis of the operating variables are, as yet, unpublished.

An attempt to use a complex system in a new-type extractor without prior knowledge of the operating variables may lead to confusing results. This paper describes the operating characteristics of the Podbielniak centrifugal extractor using a simple and easily analyzed system whose equilibrium curve is insensitive to the temperature increase normally accompanying the passage of fluids through a high-speed rotor.

#### Description of Equipment

The centrifugal extractor used in this investigation was the Pup Model, manufactured by Podbielniak, Inc., as shown in Figure 1.

The extractor was mounted on an enclosed, laboratory-type table, 54 in. by 24 in. and 30 in. in height, which housed the 1½ hp., 220/440 v., three-phase, 60-cycle motor. Two 10-gallon tanks

held the heavy liquid (A) and the light liquid (B). On each tank was an automatic pressure-relief valve set for 225 lb./sq.in. gauge, a pressure gauge, a manual bleed-off valve for releasing the pressure, a liquid-level sight glass, a fill plug and a drain plug. Nitrogen, from cylinder (C), was used to pressurize the tanks and was controlled by pressure regulators preceding each tank. The flow of each liquid was controlled by a valve (D), and the flow rate indicated by a rotameter (E) in each line. Heat exchangers (F) were provided for heating or cooling of either fluid, and thermometer wells (G) were located in both inlet lines for temperature measurement. Pressure gauges indicated the light-liquid-in pressure (H), the heavy-liquid-in pressure (I), and the light-liquid-out pressure (J). Since the heavy-liquid-out stream was at atmospheric pressure, no gauge was required. The rotor (K) in which the actual extraction took place, was surrounded by a jacket (L) through which steam or a cold fluid could be passed to control the temperature. On the light-liquid-out line, a back-pressure regulator (M) was used to vary the

ratio of liquids in the rotor and maintain a constant light-liquid-out pressure. Both effluent streams passed through glass wells (N) so that flooding could be noted and specific-gravity readings made. Finally, the effluent liquids were collected in glass carboy receivers (O). The rotor speed was variable from 2000-5000 rev./min. through a variable-speed device set by hand-wheel (P).

The rotor (overall) was approximately 18 in. in diam. and 2 in. thick, with a holdup of 600 cc. or 0.159 gal. About 65 cc. of this 600 cc. total was in the actual contacting section and the balance in the shaft and flow passages. The maximum total throughput was approximately 450 cc./min. or 7.1 gal./hr. The operating limits of the unit were a rotor speed of 5000 rev./min., a temperature of 250° F., and a pressure of 225 lb./sq.in. gauge. All parts of the extractor in contact with the liquids were of type 316 stainless steel.

Figures 2 and 3 are schematic diagrams of the extractor useful in explaining its operation. Inside the rotor are eighteen concentric annuli

Fig. 2. Schematic diagram of flow through extractor. ▶

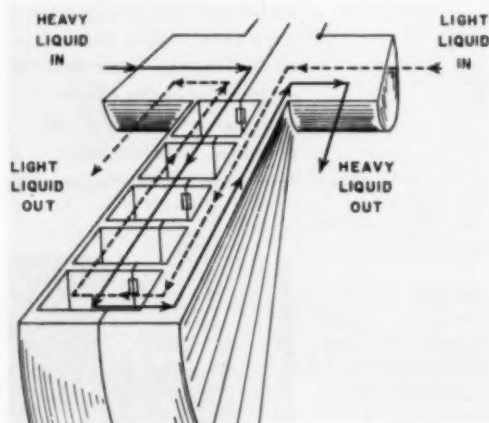
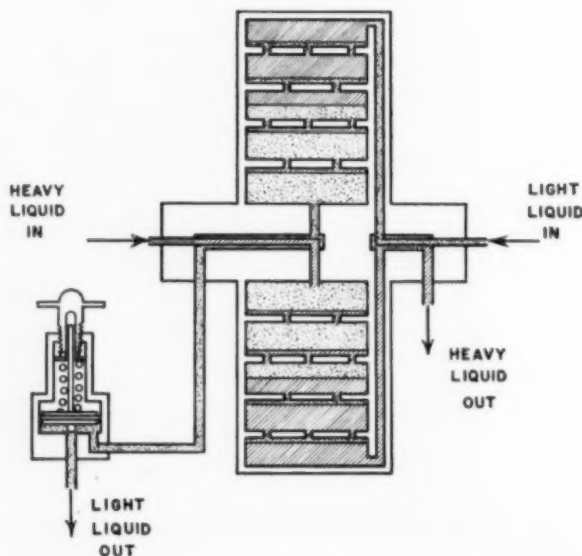


Fig. 3. Schematic drawing of extractor. ▼



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machined out of the two mating discs forming the rotor. The annuli are connected at 180° intervals by slots, approximately  $0.040 \times 0.120$  in. The slots in adjacent rings are rotated 90°. The heavy liquid passes into the rotor through a mechanical rotary seal and enters the extraction chamber near the axis. The light liquid passes through a similar seal and enters the periphery of the chamber. Centrifugal force causes the heavy liquid to be thrown outward, displacing the light liquid inward. In the zone where the heavy liquid predominates, a layer of light liquid builds up on the outer face of each ring of metal until sufficient head is developed for the liquid to spill through the slots. Similarly, in the zone near the center of the rotor, where the light liquid predominates, the heavy liquid forms a layer on the inner side of each ring of metal.

The perforations, making up only about two per cent of the cylindrical area, permit a two-way flow of fluid. As the heavy liquid, for example, passes outward through a slot hole, it forms droplets which are the dispersed phase in the continuous light-liquid layer on the outer side of the metal partition. The droplets continue radially, with some swirl component, until they coalesce with the heavy-liquid layer on the inner side of the next ring. The same is true of the light-liquid droplets moving inward through the slots and the heavy-liquid layer. The net effect is the creation of an interfacial area through which extraction may take place. The principle is that of repeated mixing and settling of the two fluids, except that the settling is accelerated by centrifugal force, and that the two layers must flow past each other until they escape into another annulus.

Conditions within the rotor during extraction may be visualized as follows (23): there is one "principal" interface, and a series of "minor" interfaces. Outward from the principal interface the heavy phase predominates; between the principal interface and the axis, the light phase predominates. In each clearance between the concentric cylinders, enough of the dispersed phase builds up to develop sufficient head to pass through the slots. Thus, even in the region near the axis where the light phase predominates, some heavy phase is present waiting to pass outward. If, because of the position of the principal interface, sufficient heavy phase accumulates in the clearance nearest the axis so as to overflow into the light-liquid-out takeoff, flooding occurs in the light-liquid-out stream. Such flooding can be corrected by increasing the back-pressure on the light liquid.

The position of the principal interface between the light and heavy liquids is controlled by the back-pressure regulator in the light-liquid-out line. Turning down the threaded stem of the regulator restricts the flow of light liquid from the unit. The light liquid flows from the rotor more easily when the regulator offers little restriction to flow. When the regulator stem is turned down the light liquid cannot flow out at its previous rate until its pressure upstream from the regulator increases and the quantity of light liquid in the rotor builds up. At a fixed setting of the back-pressure regulator, an increase in flow rate will increase the light-liquid-out pres-

sure. The light-liquid-out pressure ( $P_{LLO}$ ) can be taken as an indication of the relative amount of light liquid in the rotor at any set flow rate. Since the heavy-liquid-out stream is at atmospheric pressure, the quantity of the heavy liquid in the rotor is determined by the amount of light liquid. Thus, increasing the back-pressure at the light liquid outlet increases the holdup of light liquid in the rotor.

If the back-pressure is increased sufficiently, the light liquid builds up in the outer annulus until the light liquid passes out through the heavy liquid takeoff. This is defined as flooding in the heavy-liquid-out stream. Both types of flooding may be visually observed in the glass effluent wells.

In all cases, the heavy-liquid-in pressure ( $P_{HIL}$ ) is essentially the same as the light-liquid-out pressure, since the heavy liquid, under the influence of the gravitational field, requires only a slightly lower pressure than the light liquid in order to enter the extraction chamber.

The method of operation was, in general, as follows: The two liquids were put into their respective tanks, the filling plugs were tightened down, and pressure was applied to both tanks by means of separate pressure regulators from a manifold connected to a single cylinder of compressed nitrogen. For the system used, a pressure of 160 lb./sq.in. gauge for the light-liquid tank and 80 lb./sq.in. gauge for the heavy-liquid tank was sufficient for operation. The heavy liquid was allowed to flow into the extractor at a rate of about 100 cc./min. This served to cool the liquid seal and displace air from the rotor. When the rotor was almost filled, as indicated by heavy liquid leaving, the motor was started at the slowest rotor speed. The light liquid was then allowed to flow into the extractor at about 100 cc./min. and the speed of rotation was increased to the desired value by means of the handwheel adjustment. The actual rotational speed was read to the nearest 25 rev./min. by means of a Frahm resonant reed tachometer. When the desired operating speed was attained, the light-liquid and heavy-liquid flows were set, and the back-pressure regulator was adjusted to the desired light-liquid-out pressure.

According to the manufacturer's data, the holdup volume is about 600 cc., of which 65 cc. represents the holdup of the contacting elements only, and the balance the inlet and outlet lines and seals. Assuming that at least four changes of the liquid in the rotor are required to reach steady-state operation from start-up, at a combined flow rate of only 100 cc./min., 24 min. should be sufficient. However, the actual time required is a function of the system and must be experimentally verified. For the system boric acid-amyl alcohol-water, using a heavy liquid flow rate of 50 cc./min., a 20-min. period was necessary before steady-state operation was attained. Correspondingly shorter times were required at heavy-liquid flow rates of 100 cc./min. and 150 cc./min.

For the system used, the changes in specific gravity were so small that such data were useless for material balance calculations. Accordingly, effluent specific gravity was not taken, but effluent flows were measured and chemical analyses made.

At the completion of a run, the feed was turned off first. The extracting solvent was allowed to continue flowing at a rate of about 100 cc./min. in order to cool the seal and to wash the solute from the apparatus. The speed of rotation was then reduced to the lowest value, and the power was turned off. When the rotor had stopped, the solvent was turned off and the nitrogen was bled from the tanks.

## Experimental Investigation

### EQUILIBRIUM DATA

The system boric acid-isoamyl alcohol-water was chosen because it is not corrosive to stainless steel, involves a simple titrimetric analytical procedure, and has an equilibrium line which is reported to be straight and unaffected by temperature between 15° and 35° C. (9, 14).

Several checks on the distribution coefficient reported in the literature gave sufficient differences to necessitate a thorough study of the equilibrium curves for the various temperatures. Such an investigation was made at 25° C., and information was also obtained at 15°, 35°, and 45° C. to establish these curves, but less precisely. The boric acid and isoamyl alcohol used were reagent grade chemicals manufactured by the Baker and Adamson Co.

Measured quantities of the three components were mixed and agitated at the indicated temperatures in a constant temperature bath for several days. Then, both phases were analyzed for the boric acid concentration. Because boric acid is weakly ionized, invert sugar was used as a complexing agent, and titration was by standard alkali to a phenolphthalein end point as described by Kolthoff and Sandell (12). Ethanol (95%) was added to the sample from the alcohol phase to prevent separation into two phases during titration.

Results of the equilibrium determinations are shown graphically in Figure 4.

By the method of least squares, the values obtained for the slope,  $m$ , of the equilibrium line at the four temperatures were:

$$\begin{aligned} m_{15} &= 0.2936 \\ m_{25} &= 0.2909 \\ m_{35} &= 0.2882 \\ m_{45} &= 0.2886 \end{aligned}$$

By a statistical comparison of the four slopes, it was concluded that the distribution coefficient of the boric acid be-

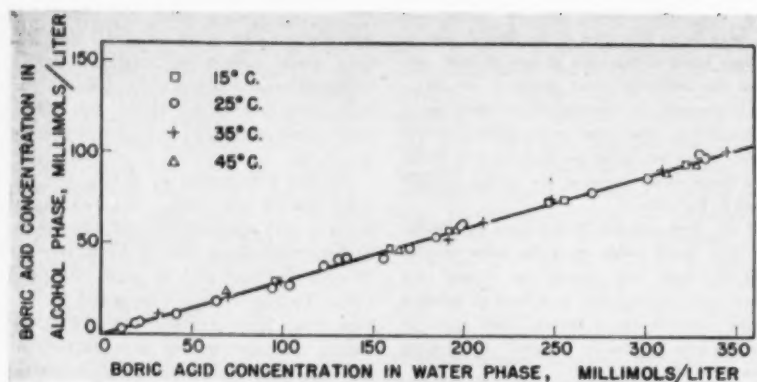


Fig. 4. Equilibrium distribution of boric acid between isoamyl alcohol and water.

tween the amyl alcohol and water is substantially independent of temperature between 15° and 45° C.

#### DETERMINATION OF NUMBER OF STAGES

For the particular apparatus and system used, the McCabe-Thiele method was selected for determining the number of equilibrium stages. As is customary in apparatus where intermediate sampling is not possible and only end concentrations (feed, solvent, raffinate, and extract) are obtainable, the operating line was assumed straight. The only conditions under which the operating line would not be straight would be those where some volume change occurred within the equipment. Isoamyl alcohol and water are not appreciably miscible, and the change in volume is not affected by the amount of boric acid present. The use of water saturated with alcohol and alcohol saturated with water justified the assumption of a straight operating line.

Colburn and Pigford (4) give the following general equation for the calculation of number of theoretical plates in countercurrent apparatus:

$$N_P = \frac{\ln[(1-J)Q + J]}{\ln(1/J)} \quad (1)$$

where  $J$  and  $Q$  are defined for absorption, distillation, and extraction. For this investigation, the extraction equation was rearranged for easier mathematical calculations and expressed in a more appropriate nomenclature.

Operating line above the equilibrium line

$$N = \frac{\log \left[ 1 - \frac{(y_1 - y_2)(m - a)}{a(y_2 - mx_2)} \right]}{\log \left( \frac{a}{m} \right)} \quad (2)$$

Operating line below the equilibrium line

$$N = \frac{\log \left[ 1 - \frac{(x_1 - x_2)(a - m)}{mx_2 - y_2} \right]}{\log \left( \frac{m}{a} \right)} \quad (3)$$

For the special case where pure solvent is used, further simplification is possible: for operation above the equilibrium line,  $x_2 = 0$ ; for operation below the equilibrium line,  $y_2 = 0$ .

#### Performance Data

##### PHYSICAL OPERATION

In studying the performance of the extractor, a distinction was made between factors which were related only to the physical behavior of two immiscible fluids in the apparatus, and factors which affected the extraction of a solute from one of these fluids into the other. In the first group the variables considered were:

- density difference of the two fluids,
- speed of rotation,
- light-liquid-in pressure,
- light-liquid-out pressure, and
- the ratio of flow rates ( $L_{LI}/L_{HI}$ ).

Variables affecting extraction of a solute were:

- concentrations of the feed and solvent,
- flow rate ratio ( $L_{LI}/L_{HI}$ ),
- speed of rotation,
- ratio of the two fluids in the rotor as indicated by the light-liquid-out pressure, and
- the total throughput of liquids.

It is of interest to derive, theoretically, an equation which relates the light-liquid-in pressure, the speed of rotation, and the density difference of the fluids. Assuming that the heavy liquid is continuous from the axis to the periphery of the rotor, the pressure it exerts at the periphery caused by centrifugal force is

$$P_{HL} = \frac{\omega^2 r^2}{2g} \rho_{HL} \quad (4)$$

The light liquid is continuous in the line until it enters the periphery of the rotor. Under the influence of centrifugal

force it, too, exerts, at the same point, a pressure of

$$P_{LL} = \frac{\omega^2 r^2}{2g} \rho_{LL} \quad (5)$$

In order that the light liquid may enter at the periphery of the chamber, its pressure must exceed, by at least an incremental amount, that of the heavy liquid. The pressure difference created by centrifugal force must be overcome by the application of an external pressure to the light liquid. The necessary additional pressure,  $P_{LLin}$ , is given as follows:

$$P_{LLin} = P_{HL} - P_{LL} = \frac{\omega^2 r^2}{2g} (\rho_{HL} - \rho_{LL}) \quad (6)$$

Then, since  $\omega/2\pi = \text{rev./sec.}$ ,

$$P_{LLin} = \frac{4\pi^2 (\text{rev./sec.})^2 r^2}{2g} (\rho_{HL} - \rho_{LL}) \quad (7)$$

The value of  $r$  was obtained as 7.71 in. or 19.58 cm. from the manufacturer's scale drawings of the equipment. The pressure in g./sq.cm. is obtained as

$$P_{LLin} = \frac{4\pi^2 (\text{rev./sec.})^2 (19.58)^2 \Delta\rho}{(2)(980.6)} = 7.718 \Delta\rho (\text{rev./sec.})^2 \quad (8)$$

Converting this to  $P_{LLin}$  in terms of pounds per square inch and expressing the speed of rotation in revolutions per minute,

$$P_{LLin} = \frac{7.718 \Delta\rho (\text{rev./sec.})^2 (2.54)^2}{(3600)(453.6)} = \frac{\Delta\rho (\text{rev./min.})^2}{32760} \quad (9)$$

The relationship was experimentally verified by operation with a number of binary systems of immiscible liquids. The systems used were benzene and water (density difference = 0.127 g./cc.), trichloroethylene and water (density difference = 0.486 g./cc.), butyl ether and water (density difference = 0.234 g./cc.), and isoamyl alcohol and water (density difference = 0.177 g./cc.). The data are graphically compared with Equation (9) in Figure 5. Results emphasize the fact that Equation (9) is only an approximation, since the assumption that the heavy liquid is continuous through the entire rotor is not always valid. In addition, the inlet lines contribute some pressure drop and additional pressure drop results from the "hydraulic swirl" of liquids in the rotor. Figure 5 can be used to determine the maximum allowable rotor speed for any system, without exceeding the 225 lb./sq.in. limit for the equipment.

Between the conditions of flooding in the light-liquid-out and the heavy-liquid-

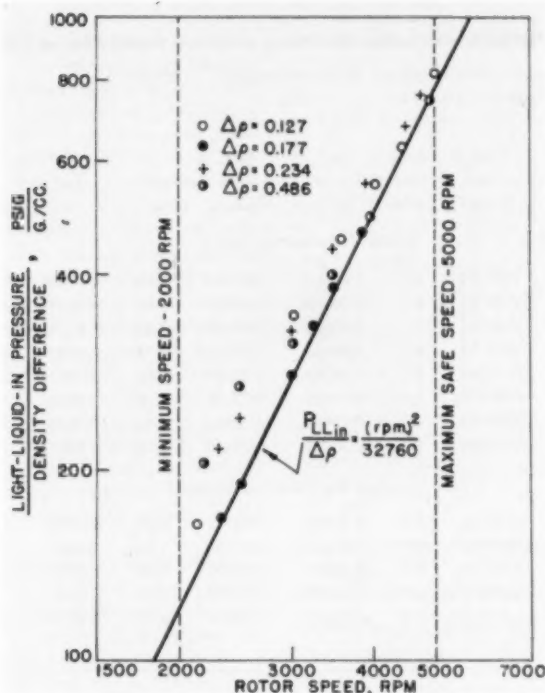


Fig. 5. Experimental relationship of rotor speed, light-liquid-in pressure, and density difference.

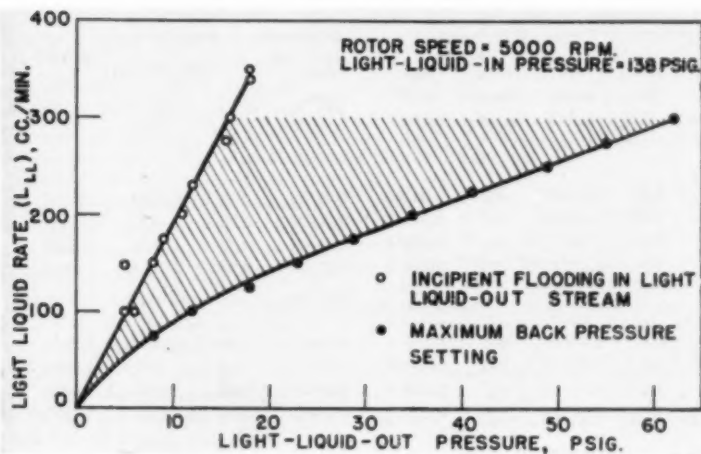


Fig. 6. Operating range for clear effluent streams at heavy-liquid flow rate of 100 cc./min.

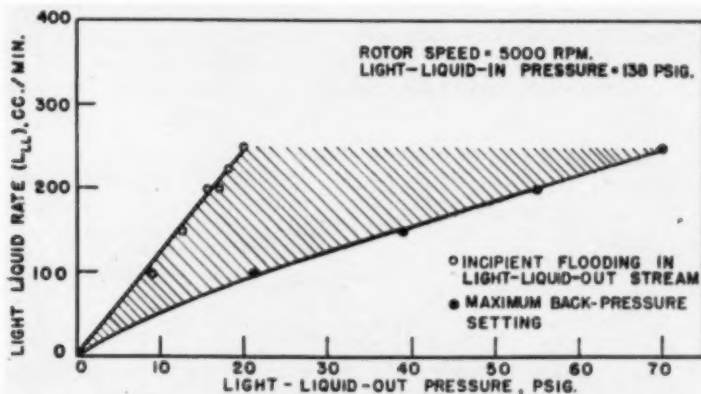


Fig. 7. Operating range for clear effluent streams at heavy-liquid flow rate of 150 cc./min.

out streams, there is a range of operation in which the principal interfacial surface lies between the two liquid take-offs. If the light-liquid-out pressure is used as a measure of the position of the interface, there should be a range of pressures (at a given flow rate ratio) at which clear streams can be maintained. Experimentally, however, flooding in the heavy-liquid-out stream was never reached at a speed of rotation of 5000 rev./min., even with the maximum back-pressure setting. Nevertheless, with the maximum back-pressure setting, an experimental limit was established in that no higher pressures were obtainable. At a given heavy-liquid flow rate and a fixed setting of the back-pressure regulator, the light-liquid-out pressure increases as the light-liquid flow rate increases. Thus, by varying both the heavy-liquid flow rate and the back-pressure setting, a series of curves may be determined (light-liquid-out pressure vs. light-liquid flow rate).

The two limiting curves, at flooding in the light-liquid-out stream and at the maximum back-pressure limit are of interest for different heavy liquid rates. These were experimentally obtained for heavy-liquid rates of 100 cc./min. and 150 cc./min. At the fixed heavy-liquid flow rate, the light-liquid rate was set at different values. For each light-liquid rate, the back-pressure regulator was adjusted until flooding just started in the light-liquid-out stream, and the corresponding light-liquid-out pressure was read. Similarly, at the other limit, the back-pressure regulator was turned down all the way, and after adjusting the light-liquid flow rate to the desired value, the resulting light-liquid-out pressure was read. Figures 6 and 7 show the operating range for the heavy-liquid rates of 100 cc./min. and 150 cc./min. For the limit of incipient flooding in the light-liquid-out stream, the relationship of light-liquid-out pressure to light-liquid rate is a straight line. For the limit of maximum back-pressure with the regulator used, the relationship is a curve. This would indicate that the back-pressure regulator served more as a throttling valve than as a regulator. Operation at a light-liquid-out pressure lower than that of incipient flooding in the light liquid-out stream results in flooding in the light-liquid-out stream. Operation at a pressure higher than that of the maximum back-pressure setting was not possible without an additional valve in the light-liquid-out line. Figures 6 and 7 are valid only for the boric acid - isoamyl alcohol - water system, since the light-liquid-out pressure is dependent on the densities of the two phases.

The heavy-liquid-in pressure, as mentioned before, is essentially the same as

the light-liquid-out pressure. The light-liquid-in pressure is unaffected by changes in the back-pressure, so long as there is no flooding in the heavy-liquid-out stream. At lower speeds of rotation, it should be possible to attain flooding in the heavy-liquid-out stream, since to maintain a given light-liquid-out pressure with a reduced speed of rotation, a thicker light-liquid zone would be required. Thus, the amount of light-liquid phase will become sufficiently great to reach the heavy-liquid takeoff, and flooding will occur in the heavy-liquid-out stream.

The maximum total capacity of the apparatus at 5000 rev./min. for this system is between 425 and 450 cc./min. If this combined flow is exceeded, flooding occurs simultaneously in both streams. The capacity is less for lower rotational speeds.

#### EXTRACTION OPERATION

For the system boric acid - isoamyl alcohol - water, extraction is possible with the boric acid initially in either the alcohol or the water. Extraction from an alcohol feed into the water solvent results in an operating line above the equilibrium line. Extraction from a water feed into the alcohol solvent results in an operating line below the equilibrium line. Both conditions are of interest.

For operation above the equilibrium line, the alcohol used as feed solution was first saturated with water by agitation and prolonged batch contact. A boric acid concentration of 0.0077 g./cc. was arbitrarily selected. This corresponded to 124.5 millimoles/l., near the upper limit of the experimental equilibrium data. Subsequent alcohol feed solutions were made up by adding boric acid to the alcohol raffinate until the boric acid concentration was again at the initial value of 0.0077 g./cc. The amyl alcohol, once saturated with water, remained saturated by repeated contact with the water phase in the extractor. The standard feed solution had a specific gravity of 0.830 at 25.0° C., and the water solvent had a specific gravity of 0.999 at 25.0° C.

Since the lowest flow rate possible with the heavy-liquid rotameter was 100 cc./min. of water at room temperature, this rate was held constant, and the light-liquid rate was varied for two series of runs. Because extraction would be expected to vary for the condition of the rotor almost full of heavy liquid and for the condition of the rotor almost full of light liquid, a series of runs was made at each limiting boundary of clear stream operation. Extraction, in terms of stages, was found to be better when the rotor was full of heavy liquid. This is in accordance with the manufacturer's recommendation that the rotor be kept full of the low flow fluid, in this case the heavy fluid.

Another series of runs was made at a heavy-liquid rate of 150 cc./min., again operating at

**Table 1. Extraction from Alcohol into Water at Heavy Liquid Rate of 100 cc./min.**

Speed of Rotation = 5000 rev./min. Feed Concentration = 0.0077 g./cc.  
Solvent Concentration = 0.0 g./cc.

$L_{LL}$ (cc./min.)	$L_{HL}$	Feed conc. (g./cc.)	Solv. conc. (g./cc.)	Raff. conc. (g./cc.)	Extr. conc. (g./cc.)	Number of Stages	Mtl. balance $\left(\frac{\text{g. H}_2\text{BO}_3}{\text{min.}}\right)$		Run No.
							In	Out	
Limit: Incipient flooding in $L_{out}$									
100	1.0	0.00764	0.0	0.00030	0.00924	2.79	0.7638	0.8158	5-24
150	1.5	0.00764	0.0	0.00034	0.01370	3.91	1.1457	1.1774	5-25
200	2.0	0.00764	0.0	0.00049	0.01757	4.88	1.5276	1.5614	5-26
250	2.5	0.00764	0.0	0.00068	0.02038	5.74	1.9095	1.8096	5-27
300	3.0	0.00764	0.0	0.00104	0.02278	6.46	2.2913	2.1715	5-28
350	3.5	0.00764	0.0	0.00152	0.02481	7.76	2.6732	2.6470	5-29
275	2.8	0.00780	0.0	0.00087	0.02255	6.45	2.1456	2.2224	5-32
325	3.3	0.00780	0.0	0.00119	0.02462	7.74	2.5357	2.6142	5-33
Limit: Maximum back-pressure									
100	1.0	0.00776	0.0	0.00022	0.00754	2.62	0.7759	0.7766	5-34
150	1.5	0.00776	0.0	0.00027	0.01083	3.26	1.1639	1.1252	5-35
200	2.0	0.00776	0.0	0.00041	0.01470	3.95	1.5518	1.5563	5-36
250	2.5	0.00776	0.0	0.00072	0.01794	4.20	1.9398	1.9822	5-37
300	3.0	0.00776	0.0	0.00095	0.02076	4.94	2.3277	2.3292	5-38

**Table 2. Extraction from Alcohol into Water at Heavy Liquid Rate of 150 cc./min.**

Speed of Rotation = 5000 rev./min. Feed Concentration = 0.0077 g./cc.  
Solvent Concentration = 0.0 g./cc.

$L_{LL}$ (cc./min.)	$L_{HL}$	Feed conc. (g./cc.)	Solv. conc. (g./cc.)	Raff. conc. (g./cc.)	Extr. conc. (g./cc.)	Number of Stages	Mtl. balance $\left(\frac{\text{g. H}_2\text{BO}_3}{\text{min.}}\right)$		Run No.
							In	Out	
Limit: Incipient flooding in $L_{out}$									
100	0.67	0.00763	0.0	0.00005	0.00553	3.13	0.7634	0.7739	5-54
150	1.0	0.00763	0.0	0.00007	0.00824	3.80	1.1451	1.1479	5-55
200	1.3	0.00763	0.0	0.00008	0.01071	4.53	1.5268	1.5269	5-56
250	1.7	0.00763	0.0	0.00012	0.01334	5.24	1.9085	1.8981	5-57
Limit: Maximum back-pressure									
100	0.67	0.00763	0.0	0.00011	0.00494	2.46	0.7634	0.7419	5-49
150	1.0	0.00763	0.0	0.00009	0.00714	3.17	1.1451	1.0844	5-50
200	1.3	0.00763	0.0	0.00017	0.01021	3.60	1.5268	1.4647	5-51
250	1.7	0.00763	0.0	0.00026	0.01243	3.83	1.9085	1.7822	5-52

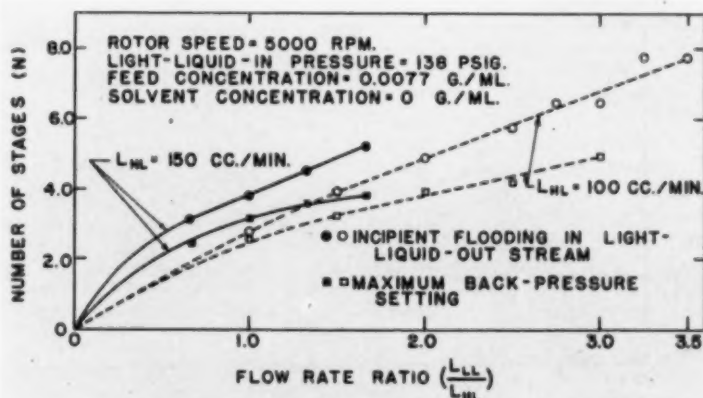


Fig. 8. Equilibrium stages, from alcohol into water.



both boundaries. The results are given in Tables 1 and 2 and shown in Figure 8. It will be noted that at the higher heavy-liquid rate, the capacity of the extractor was exceeded at a lower flow-rate ratio. For the range of flow-rate ratios possible at the higher heavy-liquid rate, however, extraction was better than for the same range at the lower heavy-liquid rate. For example, at the incipient flooding in the light-liquid-out limit, at a heavy-liquid rate of 100 cc./min. and a flow-rate ratio of 1.0, 2.79 stages were obtained. At the same limit, at a heavy-liquid rate of 150 cc./min. and a flow-rate ratio of 1.0, 3.80 stages were obtained. On the basis of holdup times, the opposite effect would be expected. That is, when the heavy-liquid rate was 150 cc./min., both liquids were passing through the extractor one and one-half times as fast as when the heavy-liquid rate was only 100 cc./min. The higher flow rates appeared to improve extraction because of increased turbulence.

Runs were attempted at a heavy-liquid flow rate of 50 cc./min., but they were not successful. At a flow-rate ratio of 4.0 and higher, the operating line approached the equilibrium line so closely, that the number of stages could not be accurately calculated. At a flow-rate ratio of 2.0, one successful run gave 4.32 equilibrium stages at the limit of incipient flooding in the light-liquid-out stream. From Figure 8 it can be seen that this point would lie below the line for operation at the same limit with a heavy-liquid flow rate of 100 cc./min., confirming the trend of poorer extraction at lower throughputs.

Two series of runs were made to study the effect of speed of rotation on extraction. At a heavy-liquid flow rate of 100 cc./min. and a light-liquid flow rate of 200 cc./min., the back-pressure was set to a value intermediate between the two limits of operation, and the speed of rotation was reduced for successive runs. A similar procedure was followed with a heavy-liquid flow rate of 100 cc./min. and a light-liquid flow rate of 100 cc./min. The data are presented in Table 3 and plotted in Figure 9. In both instances, the number of extraction stages decreased with a decrease in rotor speed. This would be expected, since the thickness of the light-liquid zone is determined by the back-pressure and the speed of rotation. One setting of the back-pressure regulator fixes the light-liquid-out pressure, and, to attain the same pressure at a lower rotor speed, the light-liquid layer must build up. Since the best extraction occurs when the rotor is full of the heavy liquid,

**Table 3. Effect of Speed of Rotation on Extraction**

Feed Rate ( $L_{HL}$ ) = 100 cc./min. Feed Concentration = 0.0077 g./cc.  
Solvent Concentration = 0.0 g./cc.

$L_{LL}$ (cc./min.)	Feed conc. (g./cc.)	Solv. conc. (g./cc.)	Raff. conc. (g./cc.)	Extr. conc. (g./cc.)	Speed of Rotation	Number of Stages	Mtl. balance $\left(\frac{g. H_2BO_3}{min.}\right)$		Run No.
							In	Out	
200	0.00769	0.0	0.00049	0.01745	5000	4.79	1.5386	1.6732	5-61
200	0.00769	0.0	0.00046	0.01647	4800	4.48	1.5386	1.5775	5-62
200	0.00769	0.0	0.00036	0.01597	4600	4.68	1.5386	1.5129	5-63
200	0.00769	0.0	0.00042	0.01596	4400	4.42	1.5386	1.5562	5-64
200	0.00769	0.0	0.00039	0.01591	4200	4.51	1.5386	1.5777	5-65
100	0.00778	0.0	0.00015	0.00772	4675	2.96	0.7779	0.7720	5-67
100	0.00778	0.0	0.00013	0.00762	4350	3.01	0.7779	0.7752	5-68
100	0.00778	0.0	0.00017	0.00747	4075	2.78	0.7779	0.7641	5-69
100	0.00778	0.0	0.00016	0.00740	3775	2.80	0.7779	0.7569	5-70
100	0.00778	0.0	0.00021	0.00721	3425	2.58	0.7779	0.7634	5-71
100	0.00778	0.0	0.00029	0.00702	3000	2.30	0.7779	0.7591	5-72

**Table 4. Extraction from Water into Alcohol at Heavy Liquid Rate of 100 cc./min.**

Speed of Rotation = 5000 rev./min. Feed Concentration = 0.0205 g./cc.  
Solvent Concentration = 0.0 g./cc.

$L_{LL}$ (cc./min.)	$L_{HL}$	Feed conc. (g./cc.)	Solv. conc. (g./cc.)	Raff. conc. (g./cc.)	Extr. conc. (g./cc.)	Number of Stages	Mtl. balance $\left(\frac{g. H_2BO_3}{min.}\right)$			Run No.
							In	Out		
Limit: Incipient flooding in $L_{LL}$										
100	1.0	0.02070	0.00000	0.01377	0.00570	2.43	1.9254*	1.8663	5-20	
200	2.0	0.02070	0.00000	0.00765	0.00534	3.48	1.9254*	1.8523	5-21	
250	2.5	0.02070	0.00000	0.00528	0.00516	4.14	1.9254*	1.7766	5-22	
300	3.0	0.02070	0.00000	0.00408	0.00493	4.30	1.9254*	1.8555	5-23	
Limit: Maximum back-pressure										
100	1.0	0.02075	0.00005	0.01516	0.00571	2.09	2.0750	2.1688	5-76	
200	2.0	0.02075	0.00005	0.01112	0.00548	2.64	2.0750	2.2300	5-77	
250	2.5	0.02075	0.00005	0.00825	0.00509	2.79	2.0750	2.1716	5-78	
300	3.0	0.02075	0.00005	0.00636	0.00474	2.89	2.0750	2.1333	5-79	

\* Heavy liquid rate 93 cc./min.

**Table 5. Extraction from Water into Alcohol at Heavy Liquid Rate of 150 cc./min.**

Speed of Rotation = 5000 rev./min. Feed Concentration = 0.0205 g./cc.  
Solvent Concentration = 0.0 g./cc.

$L_{LL}$ (cc./min.)	$H_{LL}$ $L_{LL}$	Feed conc. (g./cc.)	Solv. conc. (g./cc.)	Raff. conc. (g./cc.)	Extr. conc. (g./cc.)	Number of Stages	Mtl. balance $\left(\frac{g. H_2BO_3}{min.}\right)$		Run No.
							In	Out	
Limit: Incipient flooding in $L_{LL}$									
50	0.33	0.02037	0.00001	0.01859	0.00564	1.23	3.0555	3.1190	5-84
100	0.67	0.02037	0.00001	0.01668	0.00561	1.65	3.0555	3.1184	5-85
150	1.0	0.02037	0.00001	0.01479	0.00552	1.92	3.0555	3.0977	5-86
200	1.3	0.02037	0.00001	0.01320	0.00547	2.20	3.0555	3.1454	5-87
250	1.7	0.02037	0.00001	0.01149	0.00541	2.53	3.0555	3.1197	5-88
Limit: Maximum back-pressure									
200	1.3	0.02075	0.00005	0.01297	0.00559	2.13	3.1125	3.1124	5-83
50	0.33	0.02037	0.00001	0.01859	0.00563	1.21	3.0555	3.1649	5-89
75	0.50	0.02037	0.00001	0.01730	0.00557	1.54	3.0555	3.1385	5-90
175	1.2	0.02037	0.00001	0.01445	0.00545	1.89	3.0555	3.1829	5-91
225	1.5	0.02037	0.00001	0.01284	0.00542	2.21	3.0555	3.2939	5-92

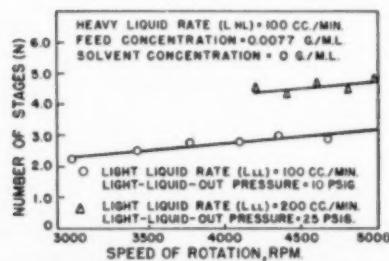


Fig. 9. Effect of speed of rotation on extraction.

as the light liquid builds up extraction becomes poorer.

If the speed of rotation is reduced sufficiently, flooding begins in the heavy-liquid-out stream. How far this reduction may be continued is dependent on the back-pressure setting. If, at 5000 rev./min., the light-liquid-out pressure is at the limit of incipient flooding in the light-liquid-out stream, the speed may be reduced the greatest amount before the light-liquid overflows at the heavy-liquid takeoff, and flooding begins in the heavy-liquid-out stream.

For the initial run when extracting from the water phase into the alcohol phase, pure isoamyl alcohol saturated with water (specific gravity = 0.826) was used as solvent. A water solution of boric acid saturated with amyl alcohol (specific gravity = 1.008) was used as feed. The boric acid concentration was 0.0205 g./cc. For subsequent runs, the alcohol extract was stripped with water in the extractor at conditions such that a minimum amount of residual boric acid was left. The boric acid concentration of the solvent used in the later runs was of the order of 0.00005 g./cc.

A series of runs was made at a heavy-liquid rate of 100 cc./min. at both limits of operation. The data are given in Tables 4 and 5 and plotted in Figure 10. As in operation above the equilibrium line, extraction is better when the rotor is filled with the heavy liquid, that is, at the limit of incipient flooding in the light-liquid-out stream.

Runs were also made at a heavy-liquid rate of 150 cc./min., again at both boundaries of the clear stream range. At these conditions, there was little difference in extraction at the two limits.

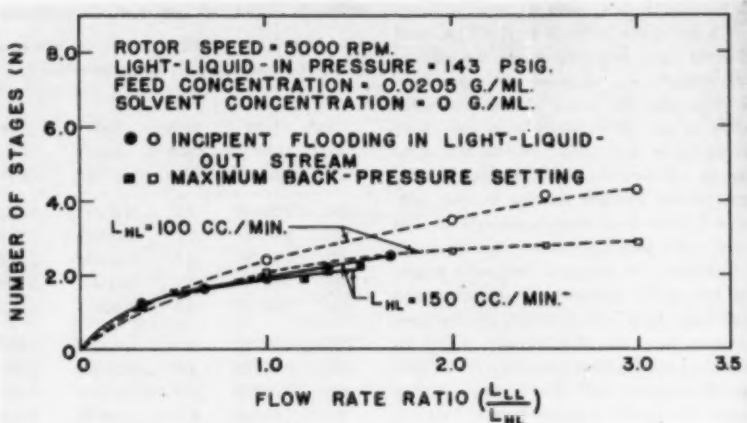


Fig. 10. Equilibrium stages, from water into alcohol.

### Comments and Conclusions

The Podbielniak centrifugal extractor represents a unique method of contacting two liquid phases. The laboratory model used in this investigation accomplished some seven to eight theoretical extraction stages under the most favorable conditions with the system boric acid-isoamyl alcohol-water. However, the number of stages is not completely determined by the study of one system—other systems may yield a larger or smaller number of stages at identical flow rates and the same speed of rotation.

Variations in the internal design of

the rotor permit a rather wide range in the number of stages from three-five to fifteen-twenty, the higher number of stages being attained at the expense of capacity. A line drawing of a larger extractor is given in Figure 11 and flow through a solids-handling unit in Figure 12. The use of perforated metal strip inside the rotor, and the streamlining of passageways when handling solids in suspension, is shown. Solutions containing as much as 15-20% by volume solids are reported handled without clogging in specially designed units. Although small particles of solid can be handled, hard solids may damage the mechanical seals

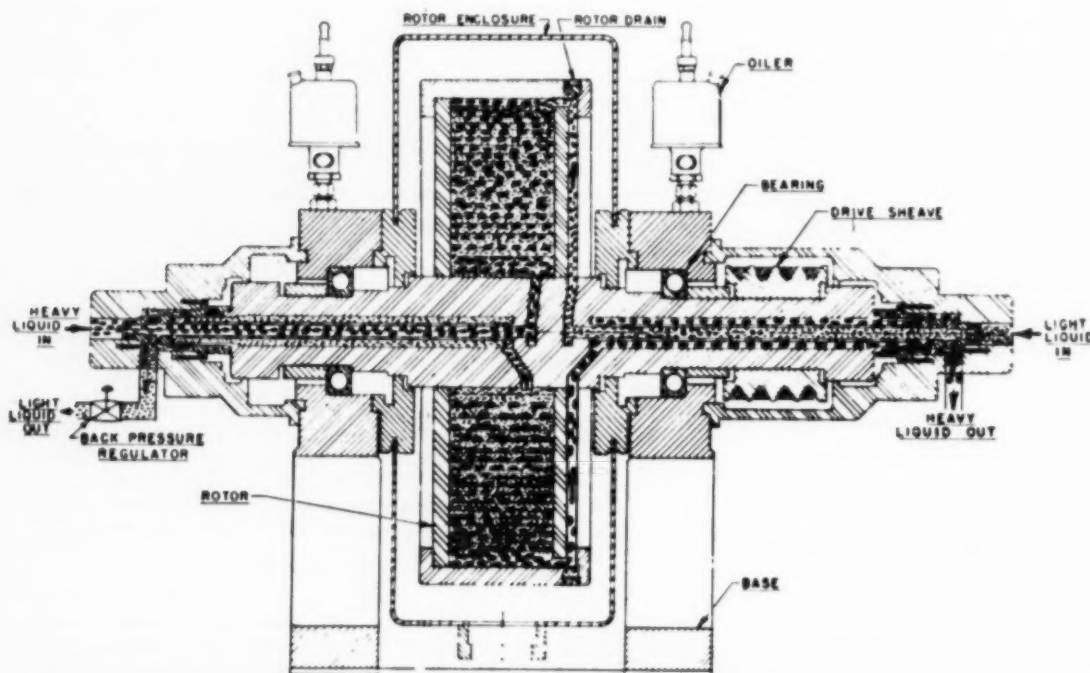


Fig. 11. Line drawing of Podbielniak centrifugal extractor

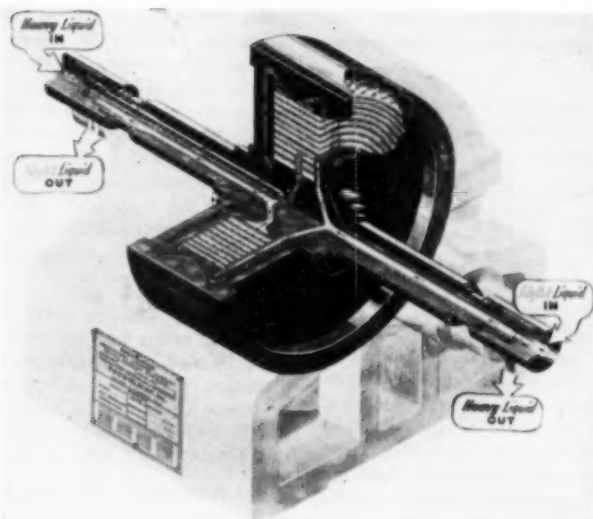


Fig. 12. Schematic diagram of flow through Podbielniak centrifugal extractor.

through which the liquids are introduced into the rotor.

The most striking feature of the centrifugal contactor is its ability to accomplish multiple-stage extraction although the liquids are in contact only a fraction of a minute. When degradation is likely to occur upon prolonged contact with solvent, this extractor gives as short a contact time as currently obtainable with countercurrent flow. Extraction between liquids having a low density difference or a tendency to emulsify, becomes feasible in a centrifugal force field. Solvents which must otherwise be diluted to obtain operable density differences can be used in pure form with uninhibited selectivity. Space requirements can often be drastically reduced by the use of such compact, high-capacity units.

Because of the complicated engineering design and construction the first cost of such contactors is high, although this cost decreases as the scale of operations increases. Maintenance costs are reported to be low, and there are instances of continuous operation for 5000 hr. without attention (23). The design of such equipment is still largely an art rather than a science. The behavior of two liquids mixed or contacted in a centrifugal force field is not generally predictable without actual pilot-plant data. To force liquids into a high-speed rotor requires pressurized feed systems, or pumps capable of developing considerable head. Although some control of the number of extraction stages is possible by proper design and operation, additional stages beyond the capacity of one unit requires duplication of equipment. Extraction with reflux or with center-feed is not possible with a single

unit, and interstage sampling or takeoff is difficult, if not impossible.

The extractor used in this investigation is not internally similar to commercial-size units. Consequently, scaling up must be done largely through empirical correlations and experience with the performance of larger machines. The laboratory model, with its small holdup but substantial capacity, is convenient for investigation of a number of different operating conditions in a relatively short time. Such data, properly interpreted, can be helpful in choosing plant-scale equipment. In some applications centrifugal extractors have already proven competitive with other types; for uses where minimum holdup and small space requirements are not so essential, centrifugal contactors will have to meet the competition of simpler devices.

#### Acknowledgment

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#### Notation

- $a$  = slope of operating line by analysis,  
 $\left( \frac{y_1 - y_2}{x_1 - x_2} \right)$ , or flow rate ratio,  
 $\left( \frac{L_{HL}}{L_{LL}} \right)$   
 $g$  = gravitational constant, 980.6 (cm./sec.)/sec.  
 $L$  = liquid flow rate, cc./min.  
 $m$  = slope of equilibrium line, 0.2909 for system boric acid-isoamyl alcohol-water

$N$  = number of equilibrium stages

$P$  = pressure, lb./sq.in. gauge

$r$  = radial distance out to light liquid inlet, cm.

$x$  = boric acid concentration in water phase, g./cc.

$y$  = boric acid concentration in alcohol phase, g./cc.

#### Greek Letters:

$\Delta\rho$  = density difference of two immiscible liquids, g./cc.

$\rho$  = density, g./cc.

$\omega$  = angular velocity, radians/sec.

#### Subscripts:

HL = heavy liquid

LL = light liquid

in = inlet stream

out = effluent stream

1 = higher concentration

2 = lower concentration

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## Discussion

**R. B. Filbert, Jr.** (Battelle Memorial Institute, Columbus 1, Ohio): Did you ever know exactly where the interface was located under a particular set of conditions? And have you ever operated a Podbielniak extractor with a system in which a phase inversion could occur?

**N. Barson:** We did make several attempts to drain the rotor at a given set of operating conditions to find out what the relative holdups of the two fluids were. However, this was impracticable, for as soon as the rotor was slowed down, the holdup changed. Therefore, we could get no quantitative measure of where the interface was, other than at the two points where flooding occurred. In most cases, these would be the two extremes of operation corresponding to an interface at the top of a column or an interface at the bottom. Answering the second question—this was the only system which we used not because we were interested in this particular system, but because we wanted primarily to evaluate the equipment.

**L. E. Hilbert** (Carbide & Carbon Chemicals Co., S. Charleston, W. Va.): Would it be possible to elaborate on the idea of the number of stages in the extractor? I have reference to the fact that five concentric circles were shown but at the same time, there are twelve stages or more. Is it possible to have twelve equilibrium stages?

**N. Barson:** Figure 3 is a schematic diagram in which the true number of physical stages is not shown. There are actually eighteen perforated rings, and these comprise eighteen physical stages in the unit. For this system we achieved eight equilibrium stages, based on the concept of the McCabe-Thiele solution. This number is valid only for this one system. However, it is possible to achieve efficiencies of a higher order with a system which permits easier extraction; that is, as high as twelve to fifteen stages have been attained with other systems.

**L. E. Hilbert:** Is it possible to have more than one equilibrium stage for each concentric ring?

**N. Barson:** No, it would not be possible by this method of evaluating the number of equilibrium stages.

**W. J. Podbielniak** (Podbielniak, Inc., Chicago 11, Ill.): I would like to clarify the point of testing stage number with a suitable ternary test system. My laboratory has checked quite closely all the findings of the author on the system boric acid, water and isoamyl alcohol. The test system, we ourselves prefer to use, because of its low cost, safety and other desirable features, is deodorized, dewaxed kerosene, water and *n*-butylamine. On this system, the Pup model, which tests only up to about eight stages on the boric acid system, will test up to twelve or thirteen stages by exactly similar methods of testing. Again, on a system like acetic acid extracted from water solution with ethyl acetate, or on the toluene, ketone, water system, stages on the Pup are still higher, up to about a test stage for every clearance between contacting elements (or about 100% mechanical stage efficiency) under same operating conditions.

I certainly agree with the statement that it is not easy to get one test stage for each mechanical clearance or stage. On the other hand, we have run tests on the Pup with the pulsing system described by Professor Berg of Cornell University, also by A. D. Little engineers, and strangely enough, we also got higher stages—up to eighteen or more—than the usual maximum of twelve stages, with kerosene, water, *n*-butylamine system. This I do not quite understand, except of course that "pulsing" introduces an entirely new mechanism than that normally provided with nonpulsing flows.

I think since no general paper on the extractor has been published, perhaps just one more point may be made—as the author explained, this is a good evaluation of a specific apparatus on a specific system. The specific apparatus is quite representative of the extractor except that it is just one mechanical embodiment of many. The commercial apparatuses are larger in diameter, and have all types of diverse contacting elements. The simplest one includes an imperforate spiral passageway, where the two liquids slither along like two snakes in countercurrent loving caress. The perforated contacting elements seem to work much better because they accomplish, by brutal centrifugal force, thorough mixing as well as centrifugal clarification. You notice that both liquids go through the holes at the same time. However, perforated trays with down spouts are also possible. So there is a wide variety of designs and that must be considered in correlating the data on the small apparatus in terms of other physical embodiments.

**G. C. Gester, Jr.** (California Res. Corp., Richmond, Calif.): The design of a perforated plate solvent extractor is critical. One optimum plate design exists for each system and set of operating conditions. Frequently, this characteristic results in a lack of flexibility which is undesirable in an experimental laboratory unit. Would the author or Dr. Podbielniak care to expand upon that thought as it pertains to the design of the extensive internal parts of the centrifugal extractor?

**N. Barson:** The Pup model is primarily for testing rather than for production, and it can be used over a fairly wide range of conditions. However, I understand that for production models, it is better to design specifically for a given use. This, of necessity, restricts the latitude of operation.

**W. J. Podbielniak:** I think that Mr. Gester is correct in stating that, in the first place, a perforated-tray column tends to be critical as against, for instance, a bubble-tray column. In the second place, the entire process of solvent extraction possesses many more degrees of freedom than the distillation process. There are systems which emulsify, systems of small density difference, of great density difference, systems which carry suspended solids, etc., which cannot be excluded from practical consideration. In fact, in the industry there are no clean liquids. They all carry suspended solids and precipitate them in the course of the extraction. The centrifugal extractor itself, I would say, has much more range and flexibility, than most gravitational extractors. That can, of course, be attributed to the centrifugal force which makes it possible to handle countercurrent liquids with much greater ease. The size of the perforations, the actual clearance between the contacting elements, the staggering or proportioning of the perforations, are all highly critical because we are mixing and also clarifying liquids in a high centrifugal field, and many things happen that we definitely do not understand. Consider how complicated is the fairly simple process of mixing with spray nozzles, and I think you will appreciate the complexity of what goes on in the machine. So, for the best performance, in other words for greatest capacity and greatest number of stages in the least costly unit, it is definitely desirable to "tailor" the contacting elements as well as the clarifying zones at the inner and outer ends of the contacting elements. There is a certain amount of entraining from clearance to clearance which can be removed by a little extra depth for clarification at the inner and outer ends, respectively, of the contacting elements. So, in that sense, for commercial purposes, there should be a great deal of custom-tailoring of the machine which does not necessarily mean that each machine is restricted. Pilot testing is definitely desirable in all cases.

(Presented at A.I.Ch.E. Forty-fifth Annual Meeting, Cleveland, Ohio.)



## A New Application of Fluidization

R. B. Thompson The Dorr Company, Stamford, Connecticut

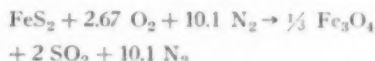
The numerous recent articles on fluidization have, with some exceptions, been concerned primarily with small-scale experimental studies and the correlation of the many physical factors involved. In at least one field of application it now appears appropriate to discuss the results of the growth of this small-scale, fundamental approach into commercial reality. Hence it is the purpose of this article to describe the Dorrco FluoSolids System as applied to the production of sulfur dioxide for use in the sulfite pulping process of the pulp and paper industry.

The sulfite process of manufacturing paper pulp is well established in many areas and has been dependent largely on elemental sulfur (brimstone). Common practice is to burn sulfur to sulfur dioxide in sulfur burners and then to absorb the sulfur dioxide in an alkaline solution or slurry to produce a bisulfite acid liquor, which is used for cooking wood chips. The desirable high concentration of sulfur dioxide in the cooking acid depends to a large extent upon the strength of the sulfur dioxide gas. With sulfur burners, the usual practice is to produce a gas containing about 18% sulfur dioxide by volume, although some mills operate with a gas as low as 12 to 14% sulfur dioxide.

Like other users of sulfur, the pulp and paper industry has faced cutbacks in its allotments of elemental sulfur. Canadian paper mills, as well as some United States mills, however, are in reasonable proximity to supplies of pyrite ( $\text{FeS}_2$ ) or pyrrhotite ( $\text{Fe}_7\text{S}_8$ ),

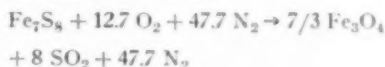
which potentially are alternate sources of sulfur. These two minerals occur abundantly in various parts of the world and are often mined along with more valuable base- or precious-metal ores with which they are frequently associated. They commonly have not been regarded as having sufficient value to warrant their use as a source of sulfur except in a very few instances, even though they may have been concentrated to a high degree of purity as a result of the recovery of the more valuable base- or precious-metal contents.

Theoretically, pyrite could be roasted with no excess air to produce a gas containing a maximum of 16.5% sulfur dioxide:



Theoretical sulfur dioxide concentration =  $2.0 / (10.1 + 2.0) = 16.5\%$

Similarly, pyrrhotite would theoretically yield only a 14.4% gas:



Theoretical sulfur dioxide concentration =  $8.0 / (47.7 + 8.0) = 14.4\%$

Because of this lower theoretical gas strength, it is desirable that these minerals be roasted under conditions that ensure the maximum gas concentration practical. The fluidized-solids technique has demonstrated that it is ideally

suited to this problem and is at present being applied in a number of paper mills throughout the world. Units are now in operation where over 96% of the sulfur contained in the raw material is being converted to sulfur dioxide gas with less than 10% excess air; i.e., gas strengths are attained equal to about 90% of the theoretical maximum.

The first such installation to employ fluidization for sulfur dioxide production is now in operation at the Berlin, N. H., mill of The Brown Co. This FluoSolids system was started in the spring of 1952.

Figure 1 is illustrative of this equipment. The heart of the system is in the reactor, where the oxidation of the sulfides takes place within a fluidized bed 16 ft. in diam. by 5 ft. deep. The reactor itself consists of a mild-steel shell lined with refractory brick and divided by a horizontal, perforated plate that serves to distribute the air uniformly over the area of the fluid bed. Feed material enters this reactor as a slurry at one point on the circumference, just above the top of the fluid bed. The roasted material, or calcine, is discharged continuously from the reactor via an overflow pipe; this overflow pipe limits the fluid bed height to 5 ft. and discharges material as rapidly as the finished solids are displaced by entering feed.

In The Brown Co. installation, the raw material consists of an iron sulfide, pyrrhotite, with minor impurities (see Table I for a chemical analysis). This material has been concentrated by flotation processes at the Vermont Copper Co. from previously discarded copper tailings and is shipped by rail to the paper mill about one hundred miles away.

The raw pyrrhotite received at the Berlin mill contains 8 to 10% water and is further diluted by controlled amounts of water into a pumpable slurry in a series of repulpers, agitators, and screens; in this form the slurry contains about 75% solids by weight and 25% water and is pumped directly into the



R. B. Thompson, assistant manager of FluoSolids sales, The Dorr Company, Stamford, Conn., has a bachelor's and master's degree from Massachusetts Institute of Technology. In 1936 he joined Dorr, where he has remained, advancing from project leader and assistant research director in the research and development department to his present position. His research on fluidization led to the commercial development of FluoSolids.

**Table 1**  
**Chemical Composition of Feed and Calcine**  
(Sampled May, 1952)

	Feed	Bed overflow	Composite of overflow and cyclone prod.	Scrubber solids
Total S	35.7	0.26	0.51	1.5
Sulfide S	35.6	0.17	0.49	1.13
Total Fe	49.1	59.3	60.9	54.6
Ferrous Fe	42.5	8.8	16.8	18.9
Cu	0.61	0.74	0.74	1.3
Zn	1.03	1.46	1.41	2.8
Insolubles	8.1	10.1	8.3	14.3

**Table 2**  
**Particle-Size Analysis**

Tyler mesh	Feed	Composite of overflow and cyclone products	Bed overflow product
		Cumulative weight %	+ mesh
35		0.8	2.4
48		2.3	5.2
65	0.8	4.9	10.7
100	3.4	11.6	30.1
150	10.1	24.1	64.9
200	21.9	41.1	94.0

FluoSolids reactor, where roasting takes place.

The water contained in the feed stream appears to be evaporated to steam almost immediately by the rapid transfer of heat from the fluidized bed, and the solid sulfides are likewise quickly heated to the bed temperature (1600 to 1650° F.). Active oxidation of the sulfur to sulfur dioxide and the iron to ferrosiferrous oxide takes place largely within the fluidized bed, although there may be a small amount of combustion of extremely fine solids taking place in the more dilute phase above the bed. Analyses of the bed material, as represented by samples of the discharged solids, indicate almost complete oxidation. Normally only 0.2 to 0.3% residual sulfur, or 99+ % oxidation, is obtained. When one considers that a small stream of solids is entering at only one point in a 16-ft.-diam. vessel, over the area of which air is rising at about 1 ft./sec. velocity, the value of the fluidized bed in rapidly mixing and reacting these two combining streams is readily apparent.

When this raw material is roasted to obtain a gas strength of 13% sulfur dioxide at 1650° F., an excess of heat is produced. If uncontrolled, there is danger of heating the solid iron oxide, which predominates in the fluid bed, to the fusion, or sticking, point. In order to hold this temperature below the sintering point, the excess heat is removed by adding water to the fluid bed. This is done at The Brown Co. by introducing a stream of water at one point in the fluid bed with an automatic control instrument to adjust the water flow to hold a selected fluid-bed temperature. So rapid is the rate of heat transfer in a fluid bed that even when water is added at one point no appreciable temperature gradient has been detected in the bed volume. A characteristic of such a unit is the remarkable uniformity of temperature observed in the bed. It has been noted that throughout this whole fluidized volume the temperature will not vary more than 20° F.

With a material as fine in particle size as this concentrate (see Table 2), a large proportion of the entering feed is entrained in the gas stream and carried out of the reactor. Gas-cleaning equipment is therefore necessary; and at Berlin two stages of hot cyclone collectors are used, followed by a Peabody scrubber. The dust collected in the cyclones is only slightly less oxidized than the solids discharging from the fluid bed;

ing and -cooling system is highly satisfactory when judged by the fact that the Berlin mill has a stringent specification for bleached sulfite pulp; at no time since FluoSolids has been used as a source of sulfur dioxide has an off-grade product been produced.

No provision is made at Brown for recovery of heat from the system. While waste-heat boilers and/or heat exchangers are entirely practicable, The Brown

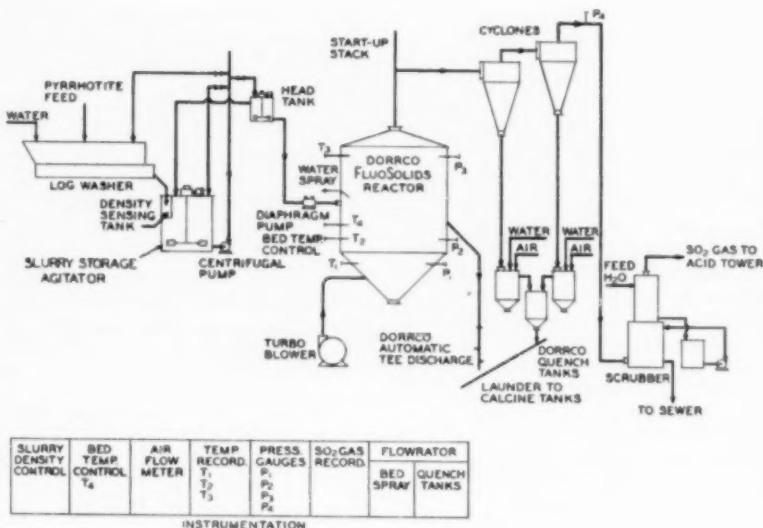
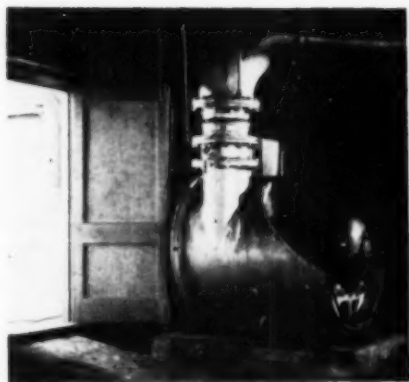


Fig. 1. Flowsheet of Brown Co. FluoSolids installation.

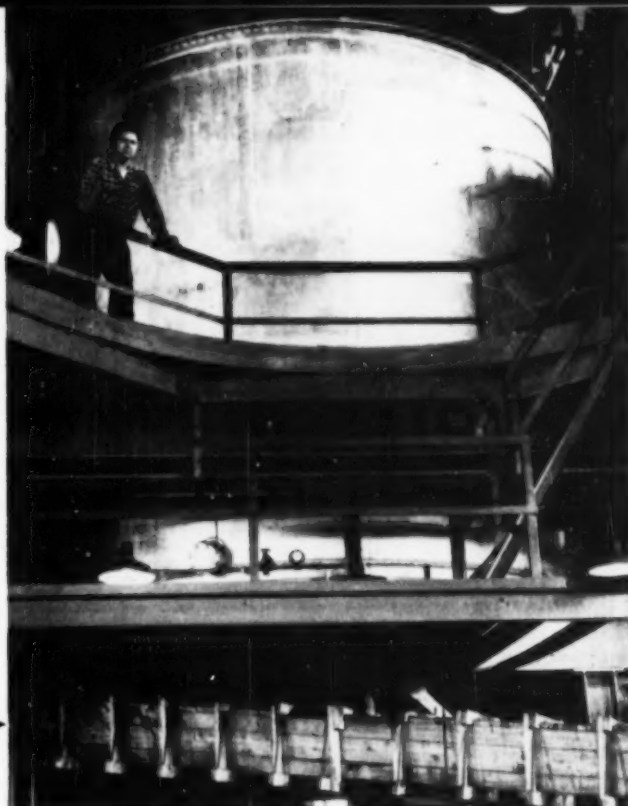
the sulfur content of the combined products is 0.51%, and the overflow alone assays 0.26%. Both the cyclone and overflow products are quenched in water and mixed together before conveying to storage or disposal. Combined they represent about 97% of the total calcine weight. The remaining 3% of the calcined solids is substantially all collected in the scrubber. The Peabody scrubber also functions as a cooler, the outlet gas being held at 90° F. by automatic control of the water. The entire gas-clear-

Co. decided that for their conditions heat-recovery equipment was not economically justified.

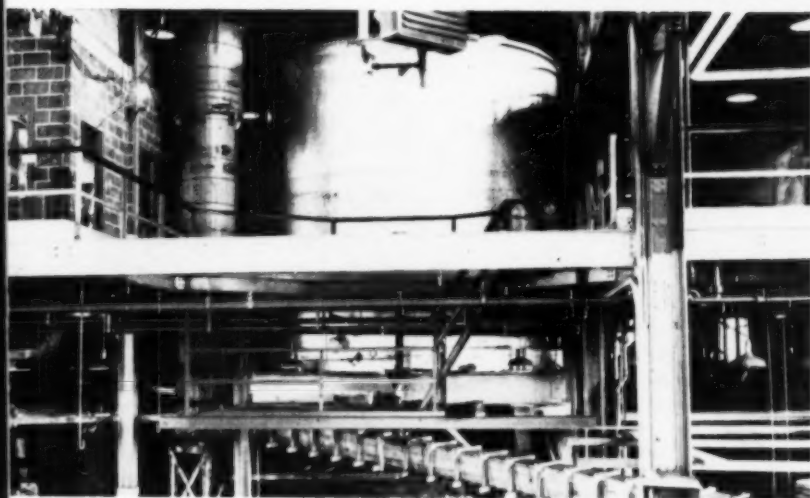
The normal operating conditions of such a unit are shown in Table 3. At the design rate, this unit is burning pyrrhotite to the extent of 75 tons/day and requires about 3600 cu.ft./min. of air for combustion. The actual space velocity, based on the dry-gas volume at reactor temperature of 1650° F., is about 1 ft./sec. Note from Table 1 that under these operating conditions the



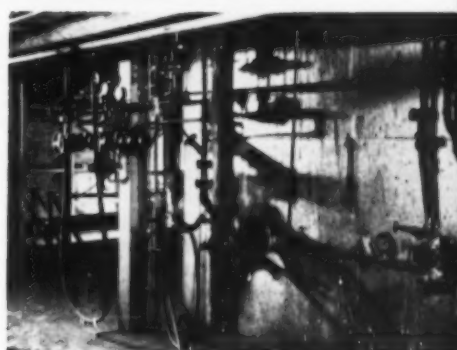
Turbine-type blower delivers air to reactor wind box at 4 lb./sq.in. gauge.



FluoSolids reactor. Calcine launder in foreground. ▶



FluoSolids reactor. Overflow discharge device in center of this view.



Operating floor showing feed nozzles.

calcine is extremely low in total sulfur, indicating a high recovery of the sulfur as sulfur dioxide. It is also of some interest that the iron oxide content of the calcine is practically all magnetite ( $\text{Fe}_3\text{O}_4$ ). This oxide of iron is black in color and is the result of oxidation with limited air quantities. The data presented in Table I were obtained by sampling over a 24-hr. period a few days after the original start-up; since that time daily composite samples of feed and composite calcine (overflow and cyclone products combined) show average figures over 23 days of 36.1% and 0.30% total sulfur in the feed and calcine re-

spectively.

The actual operating control of this unit consists of setting the air supply and adjusting the rate of slurry fed by speed changes on the pump until the maximum safe gas concentration has been reached. Automatic control devices are being used in other FluoSolids systems to adjust the feed rate to hold a desired gas strength. The main operating variables are the rates of air flow and of feed introduction, both of which are subject to remote control through suitable instrumentation. Thus such an installation is subject to immediate adjustment to meet varying capacity con-

ditions. Operation of this plant has demonstrated its flexibility in meeting demands from 60 to 130% of design capacity. Operating labor required for the FluoSolids system, exclusive of concentrate and calcine handling, amounts to one man per shift, and power consumption is estimated at 66 kw./ton of sulfur.

An outstanding advantage of fluidization in this application is the ability to produce reasonably strong gases from iron sulfides. With pyrrhotite, The Brown Co. unit consistently produces a gas containing about 13% sulfur dioxide by volume on a dry basis and 0.2% sulfur trioxide or less; whereas the theoretical maximum gas strength obtainable would be 14.4% sulfur dioxide. Pyrite is, of course, a more desirable raw material than pyrrhotite, since the higher ratio of sulfur to iron in pyrite permits a stronger gas. With pyrite this

Table 3

Operating Conditions of FluoSolids Reactor of Brown Co. 16  $\phi$  unit, May, 1952

Air flow, cu.ft./min. @ 68° F. and 1 atm. ....	3600
Feed rate, dry tons/24 hr. ....	75
Feed slurry	
% solids by wt. ....	73
lb./min. ....	141
Temperature-control water, gal./min. ....	2.5
Total water added to fluid bed, lb./min. ....	58
Fluid-bed conditions	
Temperature, ° F. ....	1610
Bed density, lb./cu.ft. ....	77
Space velocity (dry-gas basis), ft./sec. ....	1.1
Space velocity (wet-gas basis), ft./sec. ....	1.5
Stack-gas analysis	
% Volume dry basis SO <sub>2</sub> ....	13.0
SO <sub>2</sub> ....	0.2
O <sub>2</sub> ....	1.0

unit would be expected to produce a gas containing 15% sulfur dioxide. Such a unit is, according to present information, the only type of roaster available for producing these gas strengths with nearly complete oxidation of the sulfur to sulfur dioxide.

An additional advantage accruing to the Dorco FluoSolids system is that it is extremely simple to operate and control. Experience has shown that these units can be shut down and started up with no more effort than that required to push a few buttons controlling the electric motors. Over the Fourth of July holiday in 1952, The Brown Co.'s unit was shut down for 77 hr. On the following Monday morning, it required only ½ hr. to put the whole operation on stream again. Shutting down is merely a matter of pushing buttons on the feed-pump and the blower motors and closing the manually operated valve on the temperature-control water. During the shut-down periods, the large mass of solids contained in the reactor loses heat very slowly—at a rate of 5 to 10° F./hr. in a 16-ft. unit. At the end of this 3-day shut-down the bed temperature was still sufficiently hot to permit combustion; and getting back into production of sulfur dioxide required only that the feed plus air be introduced once again into the fluidized bed.

#### Economics of Sulfur Dioxide from Pyrite or Pyrrhotite

Generally, the matter of transportation of raw material is the most important factor influencing the cost of obtaining sulfur from iron sulfide. Paper mills near sources of pyrite or pyrrhotite will find that a careful study of their location may indicate that these raw materials represent a cheaper source of sulfur dioxide than elemental sulfur. When pyrite can be delivered to the user at \$10/short ton, the economics, including both fixed charges and direct operating expense, are favorable to pyrite

roasting when the cost is compared with a delivered cost of sulfur in Canada and northern United States of about \$35/short ton.

As a further economic incentive there are indications that the desulfurized calcine from the FluoSolids roaster may find a market as an iron ore. Here again transportation charges are all important, but in very special cases the proximity of iron sulfide supply, paper mill, and steel mill may alter the economics in favor of pyrite roasting. For many cases, however, the economic comparisons cannot depend on selling the iron ore. The small tonnages of sulfur and consequently of iron ore available from the calcine at even the largest paper mills will in general not justify the added handling, processing, and transportation charges required to obtain the iron ore credit.

At large acid works, however, the picture is somewhat different. When 300 to 500 tons of sulfuric acid are manufactured daily, the iron ore tonnages available are sufficient to warrant an investment in the added processing (sintering) plant for recovery of the calcine as an iron ore suitable for charging to a blast furnace. Under these conditions a delivered price of \$30 per ton of sulfur is about competitive with \$10 for pyrite.

Very soon a total of eight different paper mills and four sulfuric acid manufacturers will be operating FluoSolids systems to supply major portions of their vital sulfur dioxide from pyrite or pyrrhotite. Where a decade ago fluidization met the needs for expansion in the petroleum industry for national defense, today it appears that this same technique will contribute to the current defense program by making available hitherto untapped sources of sulfur.

#### Discussion

J. V. Ward (Gulf Research & Development Co., Pittsburgh, Pa.): The density of

the solids was given as 77 lb. Is that the fluidized density of the pyrrhotite bed?

R. B. Thompson: Yes.

Ward: In general, that is quite a bit heavier than normal, as we are accustomed to thinking of normal in a fluidized bed of a fluid catalytic-cracking unit. Have you obtained particle densities of the charge as such and of the product as such, and, if so, what were these results? I am referring to skeletal densities. Is this material porous in nature?

Thompson: It is somewhat porous. We consider the apparent specific gravity of this material in air to be about 3.0.

Ward: There is another factor too, then. The charge went in with 78% finer than 200 mesh, but the product that came out had only 59% finer than 200 mesh. Do you have any details on the sizing of those fractions of finer than 200 mesh?

Thompson: There is some agglomeration taking place.

Ward: You evidently have a perforated grid plate of some type. Just what specific local grid-hole velocity do you employ to get a good distribution in the bed?

Thompson: I can't answer in those terms since I don't know what the entering gas velocity is. We take a substantial pressure drop across that distribution plate, anywhere from 5 to 10 in. of water column.

G. D. Creelman (The M. A. Hanna Company, Cleveland, Ohio): Mr. Thompson indicates that the water used in the slurry feed and for cooling the bed accounts for about one-third of the product-gas volume. I would like to ask him for further discussion of the economic and technical advantages of substituting a waste-heat boiler for removing the heat of reaction.

Thompson: As I indicated, it is entirely possible to recover a good deal of heat from this unit. Most of the other paper mills that are installing this type of system for roasting pyrite or pyrrhotite, are putting a heat exchanger on the Peabody scrubber cooler. This recovers warm water, which they use in the mill, and also eliminates a loss of sulfur from the scrubber by recirculating that water. Now that recovers only a portion of the total heat which could be recovered.

Acid manufacturers are usually interested in recovering high-pressure steam, and waste-heat boilers are installed on these units. With such a boiler operating on stack gas, using about the same conditions that I defined in the paper, roughly a pound of steam can be produced per pound of pyrite. If you can get the pyrite or pyrrhotite in the dry form and feed it dry, you could produce a good deal more steam simply by controlling the temperature by other means such as gas recirculation. These are refinements and developments now being worked on for additional heat recovery from such a system.

(Presented at A.I.Ch.E. Chicago meeting)



# The SO<sub>2</sub> Extraction Process for Aromatics Recovery

W. F. Wilkinson, J. R. Ghublikian, and P. Obergfell

Stone & Webster Engineering Corporation, Boston, Massachusetts



W. Floyd Wilkinson graduated from the University of Michigan in 1938 with a B.S. degree in chemical engineering. Since graduation he has been employed by E. B. Badger & Sons Co., now the Badger Process Division of Stone & Webster Engineering Corp. As a process engineer in this company, he has been closely concerned with the SO<sub>2</sub> process from pilot plant work to design and operation of the commercial plant, as well as with general refinery and chemical plant design.



John R. Ghublikian graduated from Tufts College in 1939 with the degree of B.S. in chemical engineering. He has been with his present company for thirteen years, during which time he has carried out assignments in pilot plant development, plant operation, and process design of numerous petroleum and chemical installations. During the past six years he has also been supervisor of the process department laboratories.



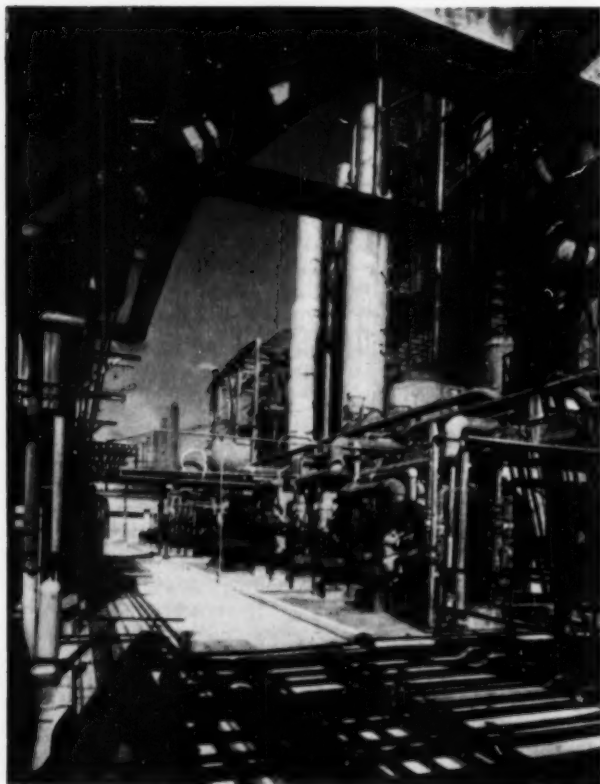
Paul Obergfell, a sales engineer in the New York office of the Badger Process Division, Stone & Webster Engineering Corp., graduated from Technische Hochschule, Karlsruhe, Germany, in 1928. He came to this country in 1932 as a sales engineer of the Edeleanu Co., pioneers in solvent extraction, and managed the U. S. branch of that company from 1936 to 1939. Subsequently he joined the E. B. Badger & Sons Co.

The SO<sub>2</sub> extraction process has enjoyed a unique position in the solvent refining of petroleum. Although sulfur dioxide was the first solvent to be used commercially (1912) for the separation of aromatics from petroleum distillates, it is still without equal as a single solvent for the extraction of aromatics from the full range of petroleum distillates.

The primary purpose of the first SO<sub>2</sub> extraction units which were called Edeleanu units after their originator, Lazar Edeleanu, was the removal of aromatics from burning oils, yielding a paraffinic raffinate. In the past two decades, the process has proved to be of increasing utility for the simultaneous production of high solvency extracts and high quality raffinates. Since 1940, with the advent of the catalytic reforming processes, the emphasis on the production of a high purity extract has increased, and, in some instances, the extract is now the principal product. The present interest in the production of high purity aromatics by the improved catalytic reforming processes has suggested a review of the SO<sub>2</sub> extraction process for the separation of aromatics, including benzene.

Liquid sulfur dioxide is particularly suitable as a solvent for the recovery of aromatics. It is completely miscible with aromatic hydrocarbons over an extremely wide temperature range, while the solubility of naphthene and paraffin hydrocarbons is limited and decreases with decreasing temperatures. Recoveries of 80 to 95 per cent of the aromatics are thus easily obtained for hydrocarbons over a wide boiling range. This high recovery of aromatics is accompanied by the simultaneous production of a high purity, nonaromatic raffinate. Sulfur dioxide has a high specific gravity and a low viscosity, which aid in the separation of the phases in the extraction tower and permit the use of high tower loadings. It is stable at operating temperatures and because of its

These authors are associated with the Badger Process Division.



Modified  $\text{SO}_2$  extraction plant for aromatics recovery.

low boiling point it is easily recovered from all petroleum fractions with low losses. Liquid sulfur dioxide is one of the least expensive solvents in use and the sources of supply are numerous. The excellent safety record of the many plants using liquid sulfur dioxide and the high service and low maintenance record of the plants testify to the suitability of this solvent.

Figure 1 illustrates the concentration of aromatics in the extract, which may be obtained at various treating temperatures for several stocks of different volumetric average boiling point. The curves are based on plant and laboratory data for straight  $\text{SO}_2$  extraction and are typical of normal operation. High purity naphtha extracts have been made commercially by extracting at temperatures as low as  $-60^\circ\text{F}$ ., but with the development of the modified  $\text{SO}_2$  process, which will be described later, high purity extracts may be made using a minimum extraction temperature of  $-20^\circ\text{F}$ .. The quality of the raffinate produced with these extracts is independent of the quality of the extract; and, with few extraction stages, raffinates having aromatic contents of 0.5 to 5 per cent may be obtained. The quality of the extract then determines the yield, which can be calculated by a simple aromatics balance.

#### Conventional $\text{SO}_2$ Process

A flow diagram of a conventional sulfur dioxide plant is presented in Figure 2. In this plant the oil charge is first dried and then chilled to the extraction temperature before it is contacted with chilled liquid sulfur dioxide in the extraction tower. A raffinate phase consisting of a solution of sulfur dioxide in the nonaromatic oil fraction is withdrawn from the top of the extraction tower while the heavier extract phase consisting of a solution of aro-

matics in sulfur dioxide is collected in the base of the tower. The extract phase then flows through a four-stage evaporation system for the removal of the sulfur dioxide. The first stage operates at 200 lb./sq.in. gauge in order to vaporize the sulfur dioxide at a sufficient temperature to recover heat from the condensing vapors. The second stage operates at the condensing pressure of the sulfur dioxide, about 80 lb./sq.in. gauge, and the next two stages operate, respectively, at atmospheric pressure and at a moderate vacuum. The sulfur dioxide vapor recovered from the latter two stages is compressed to the condensing pressure. The raffinate recovery system is identical except that the first 200-lb. stage is not used because of the much lower concentration of solvent in this phase.

With suitably designed evaporators and compressors, this plant is capable of treating any distillate from a depentanized naphtha to a heavy gas oil with treating temperatures from  $-20^\circ\text{F}$ . to  $+60^\circ\text{F}$ ., and with 175-200 lb./sq.in. gauge steam as the heating medium. With a circulating hot gas oil as a heating medium, the design may be simplified by eliminating the final vacuum stages; and for plants which will treat only naphthas, both the atmospheric and vacuum stages may be omitted.

Typical treating conditions for several different boiling range stocks are shown in Tables 1 and 2. Table 1 refers to an operation at the Abadan refinery of Anglo-Iranian Oil Company, Ltd., when a special naphtha cut from Iranian crude is treated (5). The 75 per cent aromatic concentrate produced was used as a blending stock in aviation gasoline and the raffinate was further fractionated into nonaromatic gasoline components and a reformer feed stock. The recovery of each aromatic hydrocarbon is approximately the same, averaging around 94 wt. %.

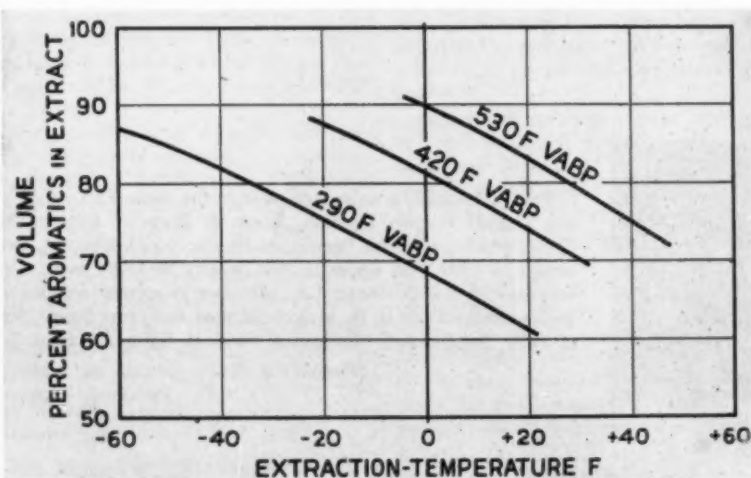


Fig. 1. Effect of extraction temperature on aromatic concentration in extract.

TABLE 1.—SO<sub>2</sub> EXTRACTION OF STRAIGHT RUN IRANIAN NAPHTHA (5)

Treating Conditions						
Vol. % SO <sub>2</sub> , basis charge			75			
Temperature, ° F.			-20			
ANALYSES OF FEED STOCK AND PRODUCTS						
Group	Aromatic Hydrocarbon		Charge	Extract	Raffinate	Recovery of Aromatics to Extract, %
C <sub>6</sub>	Benzene	wt %	0.1	0.3	0.01	....
C <sub>7</sub>	Toluene	wt %	6.8	30.6	0.6	93
C <sub>8</sub>	Ethyl benzene	wt %	1.6	7.4	0.1	95
	m-xylene	wt %	3.7	17.3	0.2	96
	p-xylene	wt %	1.3	5.8	0.1	93
	o-xylene	wt %	1.5	7.1	0.1	96
C <sub>9</sub> & C <sub>10</sub>	Aromatics	wt %	1.7	7.4	0.2	90
	Total aromatics	wt. %	16.7	75.9	1.3	93.8
	Total paraffins	wt. %	54.5	14.2	63.2	
	Total naphthenes	wt. %	28.8	9.9	35.5	
Yield		wt. %	100.0	20.6	79.4	

TABLE 2.—SO<sub>2</sub> EXTRACTION OF STRAIGHT RUN DISTILLATES

	Mid-continent Kerosene	Wyoming Gas Oil	
<b>Charge Stock</b>			
Gravity, ° API .....	42	36	
ASTM, IBP, ° F. ....	380	365	
10% .....	405	417	
50% .....	435	528	
90% .....	470	564	
EP .....	500	650	
<b>Treating Conditions</b>			
Vol. % SO <sub>2</sub> , basis charge .....	100	125	
Temperature, ° F. ....	0	30	
Extract yield .....	Vol. %	15	23
<b>Aromatics analysis</b>			
Charge stock .....	Vol. %	14	22
Extract .....	Vol. %	82	79.5
Raffinate .....	Vol. %	2	5.0
Aromatics recovery to extract, % .....	88	82.5	

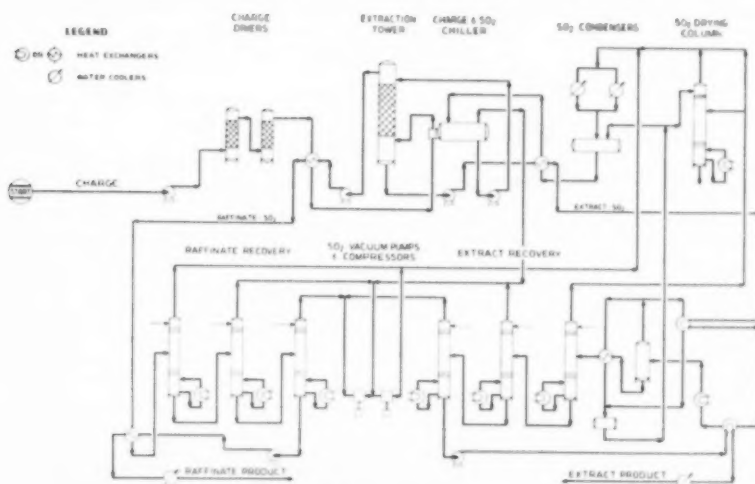
Fig. 2. SO<sub>2</sub> extraction process.

Table 2 shows the treatment of heavier stocks with high aromatic recoveries in the extracts, and with high quality raffinates. Although the raffinates produced from heavy distillates have generally been used for high quality burning oils or Diesel fuels (3, 6), they have recently served as an improved catalytic cracking stock (7). The aromatic extracts from these heavier charge stocks have many possibilities as solvents for insecticides, as plasticizers and softeners for natural and synthetic rubbers, and as feed stocks for the production of carbon black.

Typical utilities requirements for processing three different charge stocks are presented in Table 3. These figures refer to a plant operating with all steam heat and motor-driven compressors. A change in design would permit the use of fuel for the heating and compressing load, or, alternately, the compressors could be steam-driven and the exhaust steam used for process heating.

Investment and operating costs for a 10,000 bbl./stream day capacity SO<sub>2</sub> extraction plant are presented in Table 4. The figures apply to a conventional plant with all steam heat and with power driven compressors and vacuum pumps. The design is based on treating 10,000 bbl./stream day of kerosene with 100 volume % SO<sub>2</sub> at a temperature of 14° F. The same plant would be capable of treating 9,000 bbl./stream day of naphtha at 0° F. with 75% SO<sub>2</sub> or 10,000 bbl./stream day of gas oil at 30° F. with 125% SO<sub>2</sub>.

#### Modified SO<sub>2</sub> Process

It is evident from Figure 1 that there are theoretical and practical limits to the aromatic concentrations attainable by straight SO<sub>2</sub> extraction. These limitations are removed, however, by a modified SO<sub>2</sub> process first described by Defize (2) and for which a British patent was granted to the Burmah Oil Co. in 1937 (1).

In this process an extract solution obtained by conventional sulfur dioxide extraction is further enriched by contacting it with a hydrocarbon fraction of essentially paraffinic character and of a boiling range different from that of the charge oil. This so-called wash oil displaces the paraffinic and naphthenic hydrocarbons still present in the sulfur dioxide extract solution. In this contacting step part of the wash oil used as displacing agent is in turn dissolved in the mixture of sulfur dioxide and aromatics. After the removal of the sulfur dioxide the highly concentrated aromatics are separated from the wash oil by simple distillation.

For the recovery of aromatics from a catalytically reformed naphtha by this process, the wash oil may be a kerosene cut. This wash oil may be recycled in its entirety from the extract

**TABLE 3.—UTILITY REQUIREMENTS OF STRAIGHT SO<sub>2</sub> EXTRACTION PLANTS**

Charge Stock	Naphtha Kerosene Gas Oil		
Treating Conditions			
Vol. % SO <sub>2</sub> , basis charge	75	100	125
Temperature, ° F.	0	14	30
Utilities, Basis 1 bbl. charge			
Steam to process heating, lb.	63	75	85
Pumping power and lighting, kw.hr.	1.0	1.15	1.15
Power for compressors, kw.hr.	2.5	1.85	1.7
Cooling water, 85° F., gal.	750	830	930

**TABLE 4.—INVESTMENT AND OPERATING COST OF STRAIGHT SO<sub>2</sub> PLANT**

<b>Plant Design</b>	
Charge capacity—bbl./stream day kerosene	10,000
Vol. % SO <sub>2</sub> , basis charge	100
Treating temperature, ° F.	14
Plant cost including initial solvent charge	\$2,500,000
<b>Direct Operating Costs</b>	
	<b>Cents/Bbl. of Charge</b>
<b>Utilities:</b>	
Cooling water @ 1¢/M gal.	0.83
Power @ 1¢/kw.hr.	3.0
Steam @ 25¢/M lb.	1.88
Total Utilities	5.71
SO <sub>2</sub> solvent	1.0
Chemicals	0.7
Labor	1.5
Maintenance @ 3%	2.2
Royalty	None
Total Direct Operating Costs	11.11

**TABLE 5.—PILOT PLANT SO<sub>2</sub> EXTRACTION OF PLATFORMATE**

<b>Treating Conditions</b>			
Vol. % SO <sub>2</sub> , basis Platformate charge	170		
Vol. % wash oil, basis Platformate charge	75		
Temperature, ° F.	—20		
<b>Inspections</b>			
	<b>Charge</b>	<b>Raffinate</b>	<b>Extract</b>
Gravity, ° API	49.8	72.7	33.2
Specific gravity	0.7805	0.6929	0.8591
ASTM dist.			
IBP	140	142	175
50%	198	170	220
Dry point	285	288	288
Vol. % paraffins and naphthenes	48.0	97.1	5.1
Vol. % olefins	1.0	1.1	0.9
Vol. % aromatics			
Benzene	12.1	1.2	21.7
Toluene	33.4	0.5	62.1
C <sub>8</sub> aromatics			8.8
C <sub>9</sub> aromatics			1.4
C <sub>10</sub> + C <sub>11</sub> aromatics	5.5	0.1	10.2
Total C <sub>8</sub> to C <sub>11</sub> aromatics	51.0	1.8	94.0
<b>Extraction Tower Yields, Vol. %</b>	100	46.6	53.4
<b>Distribution of Components, Vol. %</b>			
Aromatics	100	1.6	98.4
Olefins	100	52.0	48.0
Paraffins and naphthenes	100	94.3	5.7

and raffinate fractionators or it may be used on a once-through basis. Since upon contact with the extract solution the wash oil itself is subjected to sulfur dioxide extraction, the recovery of aromatics from a naphtha can be combined with the extraction of a kerosene for the production of a high-grade lamp or burning oil.

The modified SO<sub>2</sub> extraction process

was first used in this country during World War II, in a plant installed in 1941 in the Baytown refinery of the Humble Oil & Refining Co. for the Defense Plant Corp. That plant produced more than one half of the toluene which went into TNT production for the U. S. Armed Forces. Since the war the Baytown plant has largely served for the production of highly aliphatic

and aromatic solvents from a hydroformed naphtha (4).

A second plant of similar design and capacity was installed during the war at the Abadan Plant of the Anglo-Iranian Oil Co., Ltd. Until that refinery was shut down this unit was used to produce an aromatic concentrate for aviation fuel enrichment. The design permitted either a straight SO<sub>2</sub> extraction

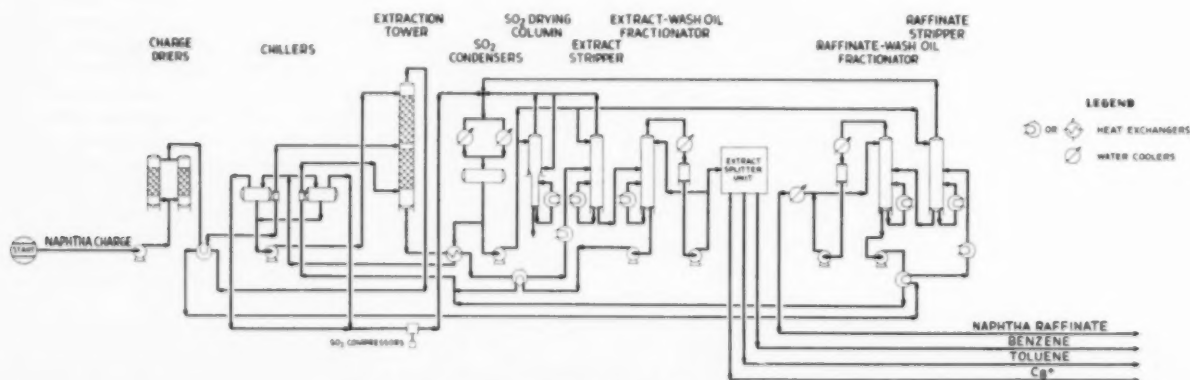


Fig. 3. Modified SO<sub>2</sub> extraction process for aromatics recovery.



at a charge rate of 16,000 bbl./stream day for the production of a 75% purity aromatic extract as previously described, or a modified SO<sub>2</sub> extraction at a charge rate of 8,000 bbl./stream day for the production of a 95% aromatic purity extract.

Both the Baytown and Abadan plants have separate contacting towers for the SO<sub>2</sub> extraction and the extract concentration. A new design has simplified the process considerably by combining the two contacting towers into a single extraction tower and eliminating the intermediate raffinate and its separate recovery system.

A flow diagram of a modified sulfur dioxide extraction plant for the recovery of aromatics from a naphtha is presented in Figure 3. The dried and chilled charge oil enters near the center of the extraction tower while the chilled sulfur dioxide enters at the top and the chilled wash oil at the bottom. The sulfur dioxide extract solution flowing downward in the tower is intimately contacted with the rising wash oil and leaves the base of the extraction tower as a mixture of naphtha extract, sulfur dioxide, and wash oil. The sulfur dioxide is removed in a single pressure stage with hot gas oil used as the heating medium. The extract is then fractionated to remove the wash oil which may be returned to the extraction tower or retained as product. The raffinate solution from the extraction tower is similarly processed for the removal of the sulfur dioxide and the separation of the wash oil.

The plant as described is designed to treat light naphthas or catalytic reformates for the recovery of high purity aromatics. It has the flexibility inherent in the SO<sub>2</sub> process of treating narrow or wide boiling range fractions with high aromatic recoveries. A plant similar to the one shown on the flow sheet has recently been described in the literature (8). This plant will produce simultaneously a nitration grade benzene and a high purity toluene-xylene fraction. The benzene contained in the extract from the unit is first separated from the heavier aromatics by fractionation and finally purified by azeotropic distillation. The toluene-xylene fraction remaining may be split into a nitration grade toluene and a high purity xylene by simple fractionation.

Pilot plant data on the production of a high purity aromatic naphtha fraction are presented in Table 5. The charge stock is a partially deparaffinized Platformate which contains 51% aromatics. The low aromatic content of the raffinate indicates that one of the major advantages of the SO<sub>2</sub> process, its high aromatic recovery, applies to the modified process as well as to the conventional SO<sub>2</sub> process.

Table 6 shows the results of separating the components in the extract by

TABLE 6.—FRACTIONATION OF PLATFORMATE EXTRACT  
STREAM YIELDS AND COMPOSITIONS

	Pre- benzene Cut IBP-70 C.	Benzene Cut 70-95 C.	Toluene Cut 95-130 C.	C <sub>8</sub> Aro- matics Cut 130-145 C.	C <sub>9</sub> Aro- matics Cut 145-168 C.
Vol. % of extract	3.1	23.8	62.4	8.8	1.9
Vol. % of Platformate	1.7	12.7	33.3	4.7	1.0
<b>Analysis of Cuts, Vol. %</b>					
Aromatics	4.0	90.5	99.6	99.6	73.7
Olefins	8.0	2.0	0.2	0.3	0.6
Paraffins plus naphthenes	88.0	7.5	0.2	0.1	25.7
Total	100.0	100.0	100.0	100.0	100.0
<b>Recovery, %, Basis Platformate</b>					
Benzene	0.5	95.0			
Toluene			99.3		
C <sub>8</sub> and C <sub>9</sub> aromatics				99.1	
Olefins	13.2	25.8	7.0	1.4	0.6
Paraffins plus naphthenes	3.0	2.0	0.1		0.6

fractionation. The low purity of the C<sub>9</sub> fraction as shown can be accounted for by the inclusion of some light ends from the wash oil. With a better fractionated wash oil, this fraction would have been comparable to the xylene fraction in purity. The 90% purity benzene cut may be purified to nitration grade by azeotropic distillation and light acid treating with an over-all recovery of more than 90% of the benzene in the charge. An operation of this kind which permits the simultaneous production of a nitration grade benzene and toluene, and a high purity xylene fraction offers

TABLE 7.—UTILITY REQUIREMENTS OF  
MODIFIED SO<sub>2</sub> EXTRACTION PLANT

Charge Stock	Naphtha
<b>Treating Conditions</b>	
Vol. % SO <sub>2</sub> , basis charge	170
Vol. % wash oil, basis charge	75
Temperature, ° F.	-20
<b>Utilities, Basis 1 Bbl. Charge</b>	
Fuel, M. B.t.u.	329
Water, 85° F., gal.	1,600
Power, kw.hr.	1.6
Steam, lb.	112

TABLE 8.—INVESTMENT AND OPERATING COST OF  
MODIFIED SO<sub>2</sub> PLANT

<b>Plant Design</b>	
Charge capacity—bbl./stream day naphtha	4,000
Vol. % SO <sub>2</sub> , basis charge	170
Vol. % wash oil, basis charge	75
Temperature, ° F.	-20
Plant cost including solvent, circulating hot gas oil heater, and benzene purification section	
	\$2,500,000
<b>Direct Operating Costs</b>	
	<b>Cents/Bbl. of Charge</b>
<b>Utilities:</b>	
Fuel	@ 10¢/MM B.t.u. 3.3
Cooling water	@ 1¢/M gal. 1.6
Power	@ 1¢/kw.hr. 1.6
Steam	@ 25¢/M lb. 2.8
Total Utilities	9.3
SO <sub>2</sub> solvent	2.0
Chemicals	1.6
Labor	3.7
Maintenance @ 3%	5.5
Royalty	None
Total	22.1

a considerable advantage over a blocked out operation to furnish these products.

The modified  $\text{SO}_2$  operation to produce high purity extracts from a light naphtha fraction makes use of a wash oil of higher molecular weight similar to a kerosene as described above. Conversely, the modified  $\text{SO}_2$  process permits the concentration of aromatics in heavier hydrocarbons by the use of a lower molecular weight wash oil. In the extraction of a gas oil by this process the lighter wash oil has the further advantage of reducing the pour point of the gas oil so that lower treating temperatures are possible with corresponding economies in wash oil circulation requirements.

Utility requirements for the modified  $\text{SO}_2$  process for the treatment of a catalytic naphtha reformat are presented in Table 7. The operation is based on producing a nitration grade benzene and a combined high purity toluene-xylene fraction. The compressors are gas-engine-driven.

Investment and operating costs for a modified  $\text{SO}_2$  extraction plant are presented in Table 8. The design is based

on treating 4,000 bbl./stream day of a catalytic naphtha reformat to produce a nitration grade benzene and a toluene-xylene fraction.

#### Conclusion

The  $\text{SO}_2$  extraction process has proved to be an extremely flexible process for removing aromatics from petroleum fractions and for recovering these aromatics in pure or highly concentrated form. By the selection of the conventional or modified process, the refiner can produce high quality non-aromatic products concurrently with either relatively high purity aromatic extracts for solvents and other uses, or essentially pure aromatics for chemicals.

The process has been used successfully on virgin and catalytically reformed or cracked distillates over a broad range from light naphthas to heavy gas oils in the same plant with no changes other than in operating conditions. The purity of the nonaromatic fractions and the recovery of aromatics into the extract has been consistently high over the entire range of distillates.

Low operating and maintenance costs are assured by the performance of a large number of plants many of which have operated for more than twenty years.

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## LETTER TO THE EDITOR

### Chemical Separation Process Methods

Sir:

As part of our nuclear energy technology it has been necessary to develop and put into large-scale practice chemical separation process methods which result in complete separations. These methods should have application in our chemical and metallurgical industries. However, the industrial potential of these methods has not been emphasized heretofore as they portend an important non-military outgrowth of the atomic energy program. These methods represent an extension of our chemical engineering practice which could be called microchemical engineering.

These new methods result from the product purification and decontamination demands of the chemical reprocessing plants serving our nuclear reactor installations. For these plants, U.S.P. or A.C.S. or other accepted purity specifications can be considered inadequate.

The techniques may involve solvent extraction, coprecipitation, volatility, ion exchange or adsorption methods. They have been made to operate in a concentration range too low for equi-

librium relationships to be applied rationally.

Industrial processes which logically stand out for first application are those used in the manufacture of fine chemicals and metallurgicals. These methods can bring to industry an industrial scale of microchemistry, which commonly requires micropipettes, micromanipulators, quartz fiber torsion balances, and other delicate microchemical research laboratory apparatus. On a full industrial scale we have learned how to perform microseparations from large bulk matrices of main process components, without delicate apparatus.

To implement these processes mechanically, new and accurate metering devices are available, capable of delivering flow rates measured in a few cubic centimeters a minute. The attendant problems of flow rate measurement and control have been solved while sensitivity, accuracy and response time characteristics have not been relaxed in instrumentation. Conventional process equipment and piping designs have been altered to satisfy the functional demands of the processes. Process operating procedures and materials transfer methods are unique in many instances, if the

separation is to be accurately performed.

As a handmaiden to these new methods, our knowledge of the chemistry of impurities to be separated has been enhanced as well. Hitherto unimportant chemical elements have become extensively studied and their behavior accurately known. Large-scale applications of these isolation processes have increased our understanding of the chemistry of the heavy elements.

Necessary to the microchemical separations processes, new analytical methods for process monitoring and control have been developed, with particular emphasis being placed on radiochemical analysis, the radioisotope tracer technique and the mass spectrograph.

Thus, a new and useful application from nuclear engineering to the chemical and metallurgical industries now can be gainfully pursued. It is an industrial process application pushing into a new sphere of purification. It brings with it improved methods in chemical engineering practice tuned to microchemical specifications. We have only to accept the challenge to explore its ultimate usefulness.

A. P. WEBER,  
Dayton, Ohio

March 26, 1953

# Thermal Conductivity of Gas Mixtures at High Pressure

## Ethylene—Nitrogen and Ethylene—Carbon Dioxide

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The theorem of corresponding states and the pseudocritical method were used to predict the conductivities of the nitrogen-ethylene mixtures with an average deviation of 5% but resulted in an average deviation of 36% for the carbon dioxide-ethylene mixtures. The experimental method is shown to be unaffected by radiation across the thin gas layers employed.

The thermal conductivities of a number of pure gases have previously been reported for pressures up to 200 atm. (5, 6). The same apparatus has been employed to measure the thermal conductivity of four mixtures of nitrogen and ethylene and two mixtures of carbon dioxide and ethylene at a temperature of 107.7° F. and at pressures up to 200 atm. The thermal conductivities of other gas mixtures at high pressure have been reported by Keyes (3, 4).

### Experimental Procedure

Gases used in the preparation of the mixtures were obtained from commercial sources and were not further purified. The purity of the gases as indicated by the manufacturer was: nitrogen, 99.8%; carbon dioxide, 99.5%; and ethylene, 99.5%.

The mixtures were prepared in small steel cylinders having a volume of approximately 400 cc. These cylinders were first evacuated and then filled to a pressure of 100 lb./sq.in. with one of the gases of the mixture. This evacuating and filling procedure was repeated five times to remove the gas which was previously in the cylinder. On the fifth filling the pressure was allowed to increase to a predetermined value. The second gas was then introduced until the final total pressure was 1500 lb./sq.in. The gases were mixed by heating the bottoms of the cylinders and cooling the tops to cause a circulation of the gases.

The composition of the nitrogen-ethylene mixtures was determined by absorbing the ethylene

in fuming sulfuric acid. The analysis of the carbon dioxide-ethylene mixtures was carried out by absorbing the carbon dioxide in a 40% solution of potassium hydroxide. Variation of the results of the analyses from the mean value was less than 0.2%.

For measuring the thermal conductivities the procedure was described in a previous paper (5). The cell was recalibrated at the time the measurements on the mixtures were made. The effect of radiation is discussed in a separate section of this paper.

The conduction of heat through a gas mixture presents a situation where the temperature gradients may give rise to concentration gradients under steady-state conditions (1, 3). During all of the measurements on mixtures, a steady state was attained over the entire pressure range. No evidence appeared of concentration gradients or circulation of the gas in the test annulus such as would be caused by a partial separation of the two component gases caused by thermal diffusion. This stability may be attributed to the thinness of the gas layer, the low-temperature difference, and the horizontal position of the cell. Although this does not necessarily indicate that there was no concentration gradient across the gas layer, it is believed that such an effect was negligible.

### Experimental Results

The four mixtures of nitrogen-ethylene contained 20.0, 38.8, 67.7, and 79.2 mole % ethylene and the two mixtures of carbon dioxide and ethylene contained 55.5 and 79.7 mole % ethylene. The measured values of the thermal conductivities of these six mixtures are tabu-

lated in Tables 1 and 2. Values for the nitrogen-ethylene mixtures have been plotted as a function of pressure in Figure 1 while the carbon dioxide-ethylene data are plotted in Figure 2. The smoothed curves for the pure gases have been plotted along with the measured thermal conductivities of the mixtures for comparison.

The nitrogen-ethylene mixtures are in fairly good agreement with the type of behavior that was expected for gas mixtures. In general, the data for the mixtures would be expected to lie on curves located between the curves for the two pure gases and reasonably spaced. In the case of the carbon dioxide-ethylene mixtures, the thermal conductivities are lower than those of either of the two pure components in the high-pressure range. Although carbon dioxide has the higher conductivity of the two pure gases, the mixture containing the greater amount of carbon dioxide has the lower conductivity in this range. At 100 atm. the thermal conductivity of pure carbon dioxide is 40% greater than that of the mixture of 55.5 mole % ethylene and 44.5 mole % carbon dioxide while that of pure ethylene is 20% greater than the mixture. The nonlinear variation of thermal conductivity with composition is somewhat more evident in Figures 3 and 4 where the experimental results are shown plotted on lines at constant pressure.

### Correlation of Data

The thermal conductivities of pure nitrogen, ethylene, and carbon dioxide can be correlated by the theorem of corre-

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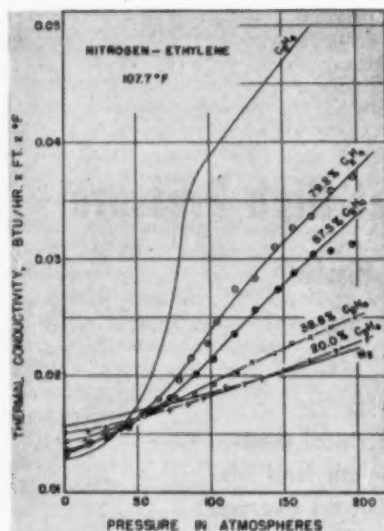


Fig. 1. Thermal conductivity of nitrogen-ethylene mixtures at 107.7° F.

sponding states (6). This theorem assumes that all gases have the same thermal-conductivity ratio when at the same reduced temperature and reduced pressure. The thermal-conductivity ratio is defined as the thermal conductivity at any pressure ( $P$ ) divided by the thermal conductivity at atmospheric pressure, where both conductivities are at the same temperature. This theorem may be extended to include mixtures by employing the pseudocritical method proposed by Kay (2). This method treats the mixture as a pure gas having a pseudocritical temperature  $T'_c$  and a pseudocritical pressure  $P'_c$  which are calculated by the following equations:

$$T'_c = x_1 T_{c1} + x_2 T_{c2} \quad (1)$$

$$P'_c = x_1 P_{c1} + x_2 P_{c2} \quad (2)$$

These pseudocritical constants are used to calculate the pseudoreduced temperature and pseudoreduced pressure which are then used in a general correlation based upon the theorem of corresponding states.

Figure 5 shows a comparison of the experimental values with those predicted by the theorem of corresponding states. The same comparison is made numerically in Table 3 which also shows the percentage deviation of the measured values from those predicted by this method. In all cases, the predicted values are higher than the experimental values. The agreement for the nitrogen-ethylene mixtures is good, the average deviation being about 5%. Values predicted for the carbon dioxide-ethylene mixtures are less satisfactory, the average deviation being about 36%. The deviation increases as the mixture approaches its pseudocritical temperature.

The prediction of the thermal conduc-

TABLE 1.—THERMAL CONDUCTIVITY OF NITROGEN-ETHYLENE MIXTURES AT 107.7° F.

Composition mole % $C_2H_4$	Pressure atm.	Thermal Conductivity B.t.u./ (hr.) (sq. ft.) (° F./ft.)
79.2	1.0	0.0133
	16.4	0.0142
	30.1	0.0149
	43.5	0.0160
	54.6	0.0166
	64.1	0.0180
	77.9	0.0195
	86.4	0.0215
	95.9	0.0228
	104.1	0.0246
	117.2	0.0274
	130.6	0.0283
	143.6	0.0310
	155.8	0.0326
	168.6	0.0336
	182.2	0.0359
	197.3	0.0370
67.5	1.0	0.0136
	16.8	0.0142
	29.3	0.0147
	43.6	0.0156
	58.4	0.0168
	71.9	0.0181
	90.4	0.0201
	101.9	0.0214
	116.9	0.0235
	130.6	0.0256
	146.0	0.0274
	156.5	0.0287
38.8	1.0	0.0143
	13.8	0.0146
	25.8	0.0152
	37.8	0.0154
	51.1	0.0164
	62.1	0.0167
	78.4	0.0181
	89.3	0.0184
	102.4	0.0192
	118.5	0.0203
	128.1	0.0211
	144.0	0.0219
20.0	1.0	0.0152
	15.6	0.0153
	28.2	0.0156
	42.9	0.0162
	55.7	0.0164
	72.1	0.0170
	84.0	0.0175
	94.9	0.0180
	110.3	0.0190
	123.2	0.0193
	135.5	0.0197
	149.6	0.0205
	167.8	0.0212
	184.9	0.0221
	206.5	0.0230

TABLE 2.—THERMAL CONDUCTIVITY OF CARBON DIOXIDE-ETHYLENE MIXTURES AT 107.7° F.

Composition mole % $C_2H_4$	Pressure atm.	Thermal Conductivity B.t.u./ (hr.) (sq. ft.) (° F./ft.)
55.5	1.0	0.0120
	12.4	0.0125
	24.8	0.0133
	34.9	0.0141
	42.9	0.0149
	50.0	0.0153
	56.5	0.0169
	62.3	0.0174
	64.1	0.0184
	73.3	0.0204
	79.9	0.0228
	85.6	0.0252
	92.4	0.0300
	104.8	0.0330
	118.7	0.0355
79.8	1.0	0.0125
	12.0	0.0128
	22.1	0.0134
	32.7	0.0141
	42.3	0.0151
	52.1	0.0166
	57.4	0.0181
	65.0	0.0190
	68.9	0.0203
	74.2	0.0220
	78.8	0.0239
	82.7	0.0260
	88.5	0.0290
	98.7	0.0326
	114.4	0.0364
	125.1	0.0374
	134.5	0.0390
	146.0	0.0407
	155.3	0.0407
	173.9	0.0443
	199.9	0.0479

tivity of a mixture using the theorem of corresponding states and pseudocritical constants may result in errors as great as 50%, even though the pure components can be correlated much more accurately. This method may be of sufficient accuracy for engineering purposes for some mixtures such as nitrogen and ethylene, but sufficient data are not available to establish a criterion for the reliability of the method in general.

The theorem of corresponding states requires that the thermal conductivity of the mixture at atmospheric pressure be known. In the preparation of Figure 5, the experimental values were used. If experimental values are not available for a particular mixture, the equation presented by Lindsay and Bromley (7)



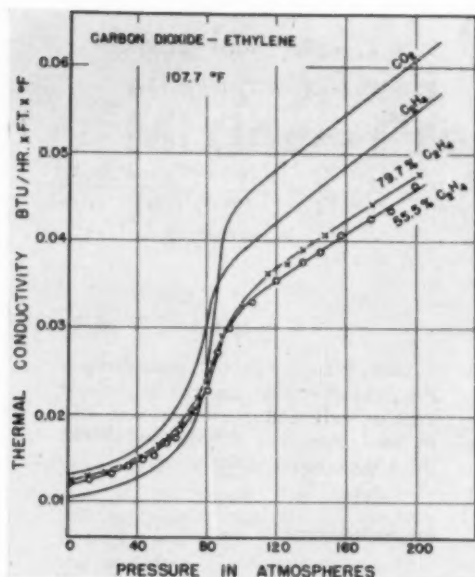


Fig. 2. Thermal conductivity of carbon dioxide-ethylene mixtures at 107.7° F.

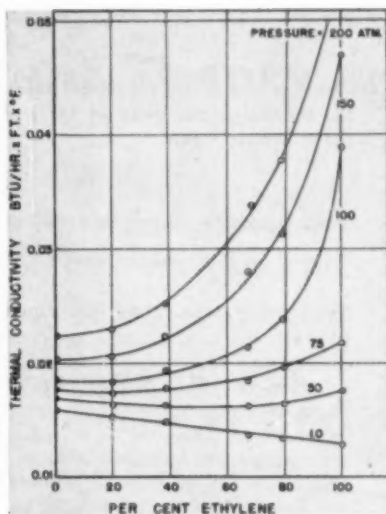


Fig. 3. Thermal conductivity of nitrogen-ethylene mixtures at constant pressure.

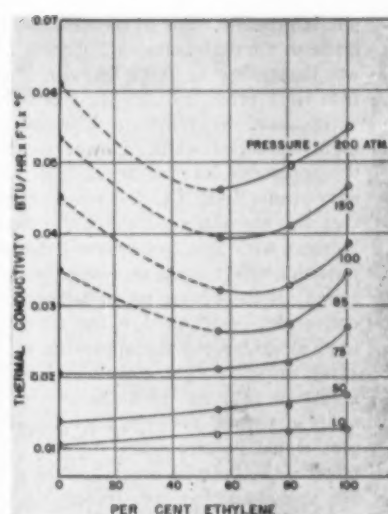


Fig. 4. Thermal conductivity of carbon dioxide-ethylene mixtures at constant pressure.

TABLE 3.—COMPARISON OF SMOOTHED EXPERIMENTAL THERMAL CONDUCTIVITIES WITH THOSE CALCULATED FROM THEOREM OF CORRESPONDING STATES

Composi- tion mole Pressure % C <sub>2</sub> H <sub>4</sub> atm.	$k_{exp}$	$k_{calc}$	% dev.
Nitrogen-Ethylene Mixtures			
79.2 200	0.0377	0.0422	11.6
150	0.0313	0.0339	8.1
100	0.0238	0.0248	3.9
50	0.0163	0.0165	0.8
67.5 200	0.0337	0.0347	6.9
150	0.0279	0.0294	4.9
100	0.0214	0.0222	3.2
50	0.0162	0.0163	0.8
38.8 200	0.0251	0.0269	7.4
150	0.0222	0.0233	5.2
100	0.0192	0.0195	1.5
50	0.0163	0.0166	1.8
20.0 200	0.0228	0.0246	8.0
150	0.0205	0.0220	9.0
100	0.0182	0.0193	5.8
50	0.0163	0.0170	3.7
Carbon Dioxide-Ethylene Mixtures			
55.5 200	0.0461	0.0665	45.3
150	0.0396	0.0575	45.5
100	0.0323	0.0457	41.1
79.8 200	0.0477	0.0627	31.1
150	0.0412	0.0536	29.6
100	0.0330	0.0412	25.5

may be employed. Of three methods tested, this equation gave the most consistently reliable results for the two systems measured. Table 4 shows a com-

parison between the experimental thermal conductivities and those circulated from the Lindsay and Bromley equation.

#### Effect of Radiation in Thermal-Conductivity Cell

These measurements were made in a horizontal annular gas layer having a thickness of 0.008 in. This gas layer was a part of a thermal resistance,  $R_x$ , which was in series with a constant thermal resistance,  $R_N$ . The relationship between the temperature differences across these resistances and the thermal conductivity of the gas is:

$$\frac{R_x}{R_N} = \frac{\Delta t_x}{\Delta t_N} = R' = \frac{\beta}{k} + \gamma \quad (3)$$

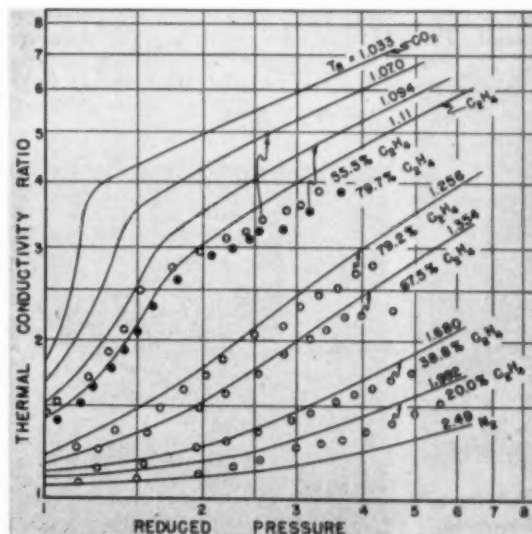


Fig. 5. Comparison of thermal conductivity ratio of mixtures with predictions by correlation using pseudo-critical constants.

TABLE 4.—COMPARISON OF EXPERIMENTAL VALUES OF THERMAL CONDUCTIVITY AT ATMOSPHERIC PRESSURE WITH THOSE PREDICTED BY LINDSAY AND BROMLEY EQUATION

Composi- tion mole % C <sub>2</sub> H <sub>4</sub>	$k_{exp}$	$k_{calc}$	% dev.
Nitrogen-Ethylene Mixtures			
79.2	0.0133	0.0133	0.00
67.5	0.0136	0.0136	0.00
38.8	0.0143	0.0144	+0.56
20.0	0.0152	0.0150	-0.86
Carbon Dioxide-Ethylene Mixtures			
55.5	0.0120	0.0117	-2.00
79.8	0.0125	0.0123	-1.28

The constants  $\beta$  and  $\gamma$  were evaluated by calibration with gases of known thermal conductivity as measured at atmospheric pressure. One of the assumptions made in the derivation of Equation (3) was that only a negligible fraction of the heat transferred through the gas layers was caused by radiation between the highly polished walls. However, since the apparatus was constructed of ordinary steel (SAE 1015), it was expected that the emissivity of the walls would increase with time to the extent that the radiation effect could no longer be neglected. If there were no radiation present, a plot of  $R'$  vs.  $1/k$  for the gases used in calibrating the apparatus would result in a straight line according to Equation (3). As the emissivity of the walls increased, however, the calibration plot would become more curved. This effect was observed several years after the apparatus was constructed. It will be shown that the curved calibration plot may be used to determine the correct thermal conductivity of the gas. It is assumed that the rate of change of the emissivity of the walls is slow enough so that the emissivity will be constant over the period of time that a given calibration is used.

Figure 6 is a diagram showing the resistances to the flow of heat in the cell. Along a radial section  $R_e$  is the resistance of the secondary gas layer which was filled with methane at atmospheric pressure during all of the measurements.  $R_f$  is the resistance of the test gas layer.  $R_a, R_b, R_d, R_e, R_g$  and  $R_h$  represent the resistances of the metal layers.  $R_a$  and  $R_b$  also include liquid film resistances which are assumed to be constant.  $T_a$  and  $T_f$  are the temperatures of the warmer and cooler water, respectively. These temperatures were controlled by thermoregulators to  $0.03^\circ$  F. and are assumed to be constant. The thermocouples at locations  $Z_1, Z_2$  and  $Z_3$  measured the temperatures  $T_1, T_2$  and  $T_3$ . The quantity of heat flowing

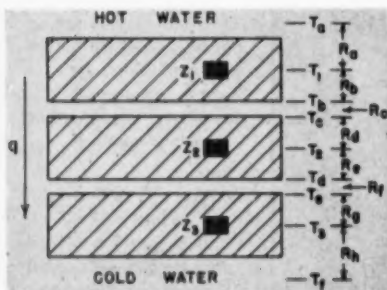


Fig. 6. Diagrammatical radial section of thermal conductivity cell showing thermal resistances.

through the secondary gas layer may be represented by:

$$q = Ak_e(T_b - T_e) + B(T_b^4 - T_e^4) \quad (4)$$

where  $A$  and  $B$  are constants and  $k_e$  is the thermal conductivity of the gas in the secondary layer.

Also:

$$T_b = T_a - q(R_a + R_b)$$

$$T_e = T_2 + qR_d$$

Substituting these values into Equation (4):

$$q = Ak_e[T_a - q(R_a + R_b) - T_2 - qR_d] + B\{[T_a - q(R_a + R_b)]^4 - [T_2 + qR_d]^4\} \quad (5)$$

But since  $T_a, R_a, R_b, A, B$ , and  $k_e$  are constants:

$$q = f_1(T_2) \quad (6)$$

Or inversely:

$$T_2 = f_2(q) \quad (7)$$

In a similar manner, the heat passing through the test gas layer may be represented by:

$$q = A'k_f(T_d - T_e) + B'[T_d^4 - T_e^4] \quad (8)$$

where  $A'$  and  $B'$  are constants and  $k_f$  is the thermal conductivity of the gas in the test annulus. Also:

$$T_d = T_2 - qR_e$$

$$T_e = T_f + q(R_g + R_h)$$

Substituting these values into Equation (8):

$$q = A'k_f[T_2 - qR_e - T_f - q(R_g + R_h)] + B'\{[T_2 - qR_e]^4 - [T_f + q(R_g + R_h)]^4\} \quad (9)$$

In this case,  $T_f, R_e, R_g, R_h, A'$  and  $B'$  are all constants. Thus:

$$q = f_3(T_2, k_f) \quad (10)$$

Substituting Equation (10) into Equation (7):

$$T_2 = f_2[f_3(T_2, k_f)] = f_4(k_f) \quad (11)$$

Substituting Equation (11) into Equation (6):

$$q = f_1[f_4(k_f)] = f_5(k_f) \quad (12)$$

Then:

$$T_1 = T_a - qR_a = T_a - R_af_5(k_f)$$

$$T_3 = T_f + qR_h = T_f + R_hf_5(k_f)$$

By definition of  $R'$ :

$$R' = \frac{T_2 - T_3}{T_1 - T_2} = \frac{f_4(k_f) - T_f - R_hf_5(k_f)}{T_a - R_af_5(k_f) - f_4(k_f)} \quad (13)$$

Or:

$$R' = f_6(k_f) \quad (14)$$

Thus, it is seen that  $R'$  depends upon the conductivity of the gas in the test annulus only and the calibration may be used regardless of whether or not there is radiation in the annuli.

#### Acknowledgment

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#### Notation

$A, B$  = constants

$k$  = thermal conductivity, B.t.u./(hr.)(sq. ft.)( $^\circ$  F./ft.)

$P$  = pressure, atmospheres

$P_c$  = critical pressure of pure substance

$P'_c$  = pseudocritical pressure of a mixture

$q$  = rate of heat transfer, B.t.u./hr.

$R$  = thermal resistance,  $^\circ$  F./(B.t.u./hr.)

$R'$  = ratio of inner to outer temperature differences

$T$  = absolute temperature,  $^\circ$  R.

$T_c$  = critical temperature of pure substance

$T'_c$  = pseudocritical temperature of a mixture

$\Delta T_s = T_3 - T_2$

$\Delta T_s = T_1 - T_2$

$x$  = mole fraction

$\beta, \gamma$  = constants in calibration equation

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# Mixing—Present Theory and Practice

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## Part II

### Flow from Impellers

The amount of liquid discharged from a rotating impeller is of significance because of its volume rate and the area through which it flows. Linear velocities are dependent on the volumetric velocities and cross-sectional flow areas. Obviously, all fluid in a mixing tank should be set in motion to produce a complete mix, so that flow from impellers must be related to some arbitrary position. Flow discharge here considered is that which flows within the boundaries of the impeller. That is, for a propeller, the flow is that which emerges at the face of the impeller at a cross-sectional area based on the propeller diameter. For a turbine (like that in Fig. 6) it is the liquid flowing radially through a cylindrical area whose diameter is that of the turbine and whose height is that of the width of the blade. It is not an easy matter to measure flow from unconfined impellers as used in mixing tanks, and several methods have been used to determine the flow.

The first measurements of flow from marine-type propellers were carried out about ten years ago by the use of an overflow technique by which water was displaced by propellers operating against zero potential head (26). Results showed that flow was directly proportional to speed. Later work revealed that for dimensionally similar three-bladed marine-type propellers, as manufactured by Mixing Equipment Co., the flow varied directly with the cube of diameter, and Equation (20) was substantiated from the data and can be written as

$$Q = KND^3 \quad (24)$$

When  $Q$  is in units of cubic feet per second,  $N$  is revolutions per second and  $D$  is in feet, the value of the constant  $K$  for water at 70° F. is 0.40.

Mention was made earlier of the fact that circular jets of water will entrain surrounding quiet liquid at rates given by Equation (11). Liquid moved by a propeller causes flow much like that of

a jet, except that the propeller flow has more turbulent energy and may entrain at a more rapid rate. Experiments are now underway to relate a pure jet action to that of a jet produced by a marine-type propeller, but until such information is available, it seems to be conservative to assume that a propeller flow will entrain at at least the same rate as a pure jet (10). In blending operations using side-entering propellers in large tanks, a useful index to mixing is the rate at which liquid is entrained per unit of power expended. Data are not yet available to determine how far a propeller jet (or even a pure jet) will continue to entrain, but apparently it will do so for at least 30 jet diameters in axial distance  $X$ . Theory of pure jets shows that if entrainment is desired for a given distance  $X$ , the most efficient use of power occurs when  $Q_e/P$  is a maximum which corresponds to a jet diameter of  $D = X/17$ .

To illustrate the significance of these relations assume that a 6-in. marine-type propeller rotating at 420 rev./min. is mounted properly in a side-entering position in a 12-ft. diam. tank of water; and that Equation (11) is applicable. Equation (24) yields the result that the discharge  $Q$  will be 21.0 cu.ft./min. For optimum  $Q_e/P$  at this given impeller size  $D$ , the optimum entrainment distance should be 8.5 ft., or 17 diameters. From Equation (11), the entrainment

will be 291 (21.0), or 61.11 cu.ft./min. Thus, for the 12-ft. tank diameter, the flow would entrain all across the tank and mixing would be taking place in the jet alone at a rate of approximately  $61.11 + 21.0$ , or 82.11 cu.ft./min. of combined streams.

Flow from radial-flow impellers is much more difficult to measure than from axial-flow propellers. Some data are available for flat-blade turbines as manufactured by Mixing Equipment Co. (26) and considerable work is now in progress in its laboratories on this subject (27, 29). A technique has recently been developed (27) whereby velocities of flow in the discharge stream of flat-blade turbines can be determined with reasonable accuracy. The method consists of work done in a glass tank, through which a flat narrow plane of light may be passed in either a vertical or horizontal plane. Small trace particles in the mixed liquid are illuminated only as they move in the plane of light, and are then photographed. The traces so made are measured for length and direction. Many photographs at various plane positions have given data on fluid motion on the principal areas of the tank for flow patterns as illustrated in Figure

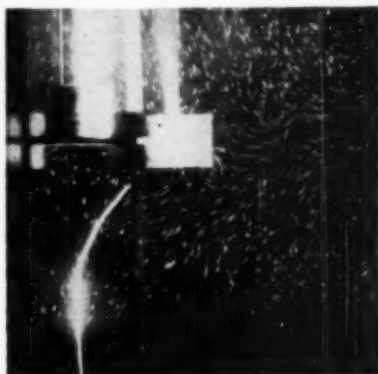


Fig. 11. Trace photograph of flow from a flat-blade mixing turbine; horizontal plane through center of impeller.

Fig. 10 (left). Trace photograph of flow from a flat-blade mixing turbine; vertical plane.

5. Figure 10 is one of the photographs taken with illuminations in a vertical plane (as the drawing of Figure 5), with water in the tank. This illustrates lines of flow and shows the discharge emerging from the cylindrical ring of the turbine in a band of flow between the top and bottom (width) of the flat blades. The picture shows only part of the tank, from the turbine shaft to the tank wall, and shows also the traces made by moving drops of immiscible liquid. Water is entrained into the discharge stream as evidenced by the traces entering the discharge from above and below and beyond the periphery of the turbine.

Figure 11 is a trace photograph for illumination in a horizontal plane directed toward the center of the blades. The rotation of the turbine in the picture is clockwise. Traces formed by the impeller are visible, and confirm the plan view of the drawing of Figure 5. A baffle is at the right center of the picture, and can be detected by the dots of particles moving vertically through the light plane at that point. Analysis of the traces shows varying velocity and angle as liquid travels toward the tank wall. By averaging thousands of traces in various traverses of the streams, the average velocities  $\bar{v}$  were determined, and from this the values of  $Q$  at different radial positions were calculated. A four-blade standard Mixing Equipment Co. turbine, 4 in. in diam., was found to have a discharge rate at 200 rev./min. in the 12-in. tank of 3.56 cu.ft./min. This agrees well with the only other flow data in the literature (26).

At constant power input the ratios of Table 2 can be used to find how discharge volume and head are affected by change of size and corresponding speed. The ratios are rigorous for dimensionally similar systems, and also for the case when tank diameter  $T$  is constant provided that Equations (17) and (20) are known to apply for the  $D/T$  ratios involved. A tabulation, for illustration, is given in Table 3 in the form of diameter, volume and head ratios for decreasing impeller speeds. Table 3 follows directly from the relations in Table 2.

TABLE 3.—IMPELLER FLOW AND HEAD RATIOS AT CONSTANT POWER.†

Speed rev./min.	Diameter $D$	Volume $Q$	Head $H$	$Q/H$
1680	0.44	0.33	3.03	0.11
840	0.66	0.58	1.74	0.33
420	1.00	1.00	1.00	1.00
210	1.52	1.74	0.58	3.00
105	2.30	3.03	0.33	9.18

† Relative values based on a speed of 420 rev./min.

Assuming a diameter and volume of one each at a speed of 420 rev./min., then if power is held constant the table shows that at  $\frac{1}{2}$  speed (210 rev./min.) the impeller diameter required is 52% greater, the flow will be 74% greater, and the head will drop to 58% of the first case. The table illustrates the fact that when large flows are desired at minimum power input, larger impellers are used at lower speeds. Conversely, if high heads are desired smaller diameters are used at higher speeds. The cost of the speed-reducing element of a mixer is a major factor in mixer price and since lower-speed equipment is more expensive than high-speed mixers, a compromise must be made between speed, size, and power for a given flow requirement for best economy of operation. The table also shows how the  $Q/H$  ratio varies with speed and size for constant power input. Note that the ratio changes rapidly with speed.

#### Turbulence

It is also possible to gain insight into turbulence by inspection of the traces in Figures 10 and 11. Analysis of traces at a given radial position shows varying velocities at these positions. Velocity fluctuations are proportional to these trace length fluctuations, for each trace is taken to be equivalent to an instantaneous velocity. Accordingly, the root mean square velocities  $\sqrt{\bar{v}^2}$  were determined. These are proportional to turbulence, and the data are being so analyzed. It is clear from the photographs, however, that there are greater fluctuations at some positions than at others. In fact, in Figure 11, part way between the impeller and wall, some traces evidently are moving in eddies or as a result of contact with a number of eddies, and analysis shows that these are the regions of greater intensity of turbulence. By such techniques determinations are being made to find where turbulence is formed to the greatest extent,

how fast it is dissipated, how much entrainment occurs, and how the effects of diameter, power, and fluid properties influence the quantity and turbulence of flow.

Preliminary results of flow from turbines indicate that equations like (24) apply to them, and that the head-flow-power relations given in Equations (18)-(23) and Tables 2 and 3 can be applied to these impellers.

There are three principal ways by which turbulence is usually initiated; all three appear to occur in mixing operation. Figure 12 illustrates the growth in instability of flow and formation of turbulence by boundary-layer or "skin-friction" effect. The figure also shows a form separation, a common method for turbulence generation. Here the fluid flows past some form or projection. The third method shown is that of fluid-velocity discontinuity, where turbulence is generated in a manner similar to a boundary-layer mechanism, except that the boundary is a slower moving element of fluid, instead of a solid surface.

It appears that by far the greater portion of turbulence in mixing tanks with the common impeller arrangements, forms by fluid-velocity discontinuity. Most of the turbulence is generated along the boundaries or the discharge streams, and wherever high- and low-velocity flows come together. Skin friction undoubtedly accounts for some turbulence, but velocities adjacent to solid surfaces are relatively low in the case of mixing in baffled conditions. Form separation plays a minor role around the impeller blade, and an even smaller role around the baffles. However, if baffles or other projections are placed close to the impeller, this effect will increase greatly.

It is of significance to note that baffles affect the entire tank flow pattern and do not simply act to form vortex-streets at the expense of swirling flow. All elements of a mixing operation (the impeller shape, position, speed, and size,

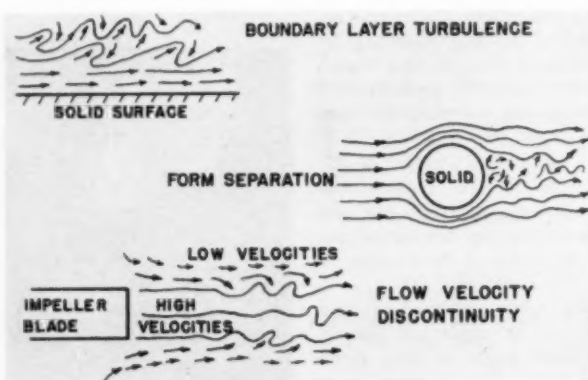


Fig. 12. Turbulence generation.



and the fluid properties, and the tank shape, size and fittings) together cause a well-defined primary and secondary set of flow motions. The three most common forms of impellers (propellers, turbines, and paddles) can be used to create any of the combinations of motions desired, provided the fluid mechanical characteristics of each are understood. Because of lack of such knowledge in the past, too much attention has been given to impeller shape and not enough to the factors just discussed.

For many years it has been recognized that some mixing operations are dominated by relatively large flows while others are best performed by relatively low flows when compared at the same power input. This is equivalent to saying that large values of  $Q/H$  are sometimes required while small values of  $Q/H$  are found to be best at other times. The head is proportional to turbulence, but it cannot easily be evaluated for open running impellers. So far, the head has been determined only for mixers by calculation, that is, by dividing power by flow. It is of interest to see the significance of head in Equation (12) and its relation to turbulence. One part of the total head term is the potential head (Equation (13)). Ordinarily, in mixing operations illustrated in Figures 2 through 5, the net potential head,  $H_{\text{potential}}$ , is zero, because the liquid level in the tank is constant. For Figure 1, however, where vortex exists, the potential head has a value. There are operations, however, where potential head is developed and used. Water treatment operations often entail the use of mixers which also elevate the flow a distance of several inches to a foot. Obviously, the discharge stream from the mixer (usually a turbine) will provide the energy necessary for the elevation. There are other times when some pumping action of an impeller is desired, as in continuous mixer-settler operations in liquid-liquid extraction, and the flow and head characteristics of the mixers must be known for accurate design. Proper design of such elements can eliminate the need for interstage pumping in these operations.

The major usefulness, however, of the head characteristic is in its relation to turbulence. Regardless of whether one or another of the pressure or friction heads is significant, the only way they can be dissipated (and the energy they typify) is through turbulence and viscous shear. Pressure heads in a flow motion are transformed to velocity heads (either by momentum transfer, Equation (4), or directly to velocity head). When they transfer by momentum in the sense of Equation (4), turbulence is produced.

If they transfer to velocity in the  $x$  direction, a velocity fluctuation is produced, and thus more turbulence. That part of the total head of Equation (15), which is the kinetic head of turbulence (in this case turbulence in the stream emerging from the impeller before pressure heads are transferred to it), is present in the  $H$  of Equation (12) and would not appear as kinetic head calculated from  $Q$ . The amount of cross flow in the secondary motion of highly turbulent streams is a large amount and the kinetic head corresponding to it is large. In turbulent flow through conduits, however, this turbulent head is constant in amount and is accounted for in the general term for friction resistance; hence, little attention has been paid to it as such. The open, expanding, entraining flows in a mixing tank involve large amounts of material in cross flow where the velocity vectors are in directions other than that of the flow, and thus the kinetic head of turbulence, proportional to  $\sqrt{v_x^2}$ , will be significant and may be large. This head is, however, a part of  $H$  in Equation (12) as are the potential and friction heads, all of which degrade to heat through the mechanism of turbulence and viscous shear. Thus,  $H$ , in Equation (13), is directly proportional to the turbulence in a mixing tank. It should be pointed out also that the average velocity ( $\bar{v}_x$ ) kinetic head will also be converted to heat through turbulence, but in the main flow stream the velocity discontinuities are less severe and turbulence therefore is generated more slowly. All energy put into the impeller stream is dissipated through turbulence and viscosity to heat, but high ratios of  $Q/H$  will degrade less rapidly through turbulence to heat than will low ratios of  $Q/H$  for the same power input.

Referring to Equations (21) and (23), and other relations in Table 2, it is clear that accurate data on power and flow characteristics enable the determination of total head, and thereby a measure of turbulence. Knowledge of the effect of speed and impeller size on turbulence then enables one to design equipment to achieve whatever ratio of  $Q/H$  may be desired for a particular process.

#### Process Requirements and Scale-Up

The foregoing discussion has dealt principally with the mechanical behavior of fluid in motion and the conditions under which different motions are achieved. Each particular chemical process may demand a unique set of flow-motion conditions for optimum results. To date, no general criterion of mixing has been found to fit more than a few mixing requirements. It is obviously necessary to create a flow pattern allowing all parts of a fluid to be inter-

mingled, but the amount of flow and the turbulence required for a given rate of mixing cannot be generalized. The requirements for rapid and complete mixing in solid suspensions, blending, heat-exchange, gas-liquid contacting, and liquid-liquid extraction are different in detail, particularly with regard to the secondary, or turbulent, flow conditions. Accordingly, it is necessary to determine mixing requirements by experiment, relating power, flow, and turbulence to some rate coefficient of performance. Further, the process requirements should be made experimentally in such terms as to be useful for scale-up to larger size equipment. Model calibrated impellers should be used in pilot-plant and bench-scale studies so that the results can be translated to large size using commercially available equipment. Specifications for mixing equipment can then be made in terms of flow pattern, power, flow, and turbulence to assure desired reaction rates.

There are various useful ways to determine mixing requirements and information for scale-up. As basic performance data become more available, it may be possible to extend any one of these methods to all types of operations. The following discussions are intended for illustrations of method, and do not limit the method to processes mentioned.

If flow or turbulence dominates the desired reaction rate, it is possible to utilize Equations like (18) and (19), to set experimental conditions to find if one or the other is dominant. These equations are approximately valid for wide ranges of  $D/T$ ; hence, for experimentation in a tank of constant size  $T$ , the impeller size can be varied and the speed adjusted according to Equation (18), so that the effect of different ratios of  $Q/H$  can be determined. For example, if at the same power input a dimensionally similar but smaller impeller gives a higher coefficient of performance, it shows that turbulence is relatively more important than flow because the smaller  $Q/H$  ratios give better performance. Conversely, if higher values of  $Q/H$  are found necessary because a larger diameter, lower-speed impeller at the same power input gives better performance, then the quantity of flow rather than turbulence dominates the operation. Larger equipment can, therefore, be specified to give the minimum (or higher)  $Q/H$  desired.

The rate coefficients of operations such as heat and mass transfer can be related to the Reynolds number (equivalent to turbulence) by the Nusselt and other dimensionless parameters (11). The general equations, consistent with dimensional analytical techniques (19, 20), are:

Tables 1 and 2, and Figures 1-9 were run with Part I in the April issue, page 161.

For heat transfer, the rate coefficient is  $h$ , and

$$f\left(\frac{hD}{k}\right)\left(\frac{c\mu}{k}\right)\left(\begin{array}{c} \text{other pertinent property,} \\ \text{or boundary ratios} \end{array}\right) = K\left(\frac{D^2 N \rho}{\mu}\right)^x \quad (25)$$

For mass transfer, the rate coefficient is  $k_L$ , and

$$f\left(\frac{k_L D}{D_a}\right)\left(\frac{\mu}{\rho D_a}\right)\left(\begin{array}{c} \text{other pertinent property,} \\ \text{or boundary ratios} \end{array}\right) = K\left(\frac{D^2 N \rho}{\mu}\right)^x \quad (26)$$

The property and boundary ratios are, for example, viscosity ratios ( $\mu_{film}/\mu_{ave}$ ); ( $D/T$ ), and others. In general, it has been found that the function relations of the dimensionless groups of these equations are exponential within practical limits. The exponent  $x$  of the Reynolds number is called the mixing slope. Figure 13 shows that the slope of the line (the mixing slope) is a significant index. When data can be correlated in this way for heat transfer (Equation (25)), or for mass transfer (Equation (26)) in extractions and absorptions (21), it is evident that a desired coefficient for any other kinematically similar mixing system will require a Reynolds number as indicated by the plot. To scale-up from such data, when mixing is performed under fully developed turbulent conditions (line C-D of Figure 9), the curves of Figure 14 can be used (20). Figure 14 shows the power per unit volume necessary at the scale-up size which will be required to produce the desired rate coefficient for dimensionally similar systems, in terms of the mixing slope  $x$ . The equations which apply for scale-up when a mixing slope  $x$  is known are

$$N_r = (D_r)^{(2x-1)/x} \quad (27)$$

and

$$P_r = (1/D_r)^{5-3(2x-1)/x} \quad (28)$$

where subscript  $r$  refers to conditions 2 to 1; hence,  $D_r$  is the ratio of diameter ( $D_2/D_1$ ) and is the scale-up. Equation (27) shows the speed ratio in terms of scale-up, whereas Equation (28) shows the power ratio in the same terms. For dimensionally similar scale-up, the volume ratio ( $V_2/V_1$ ) is equal to the cube of the scale ratio, or

$$V_r = D_r^3 \quad (29)$$

For convenience, the power per unit volume ratio can be computed as  $(P/V)_r$  by dividing Equation (28) by Equation (29). These are the values used in the plot of Figure 14.

Since the product  $D^2 N$  in the Reynolds number is significant rather than  $D$  or  $N$  alone, it is obviously possible to use different values of  $D$  and  $N$  to achieve the same Reynolds number, although different amounts of total power would be involved. Relations like Figure 13 and Equations (17), (25), and (27) are so firmly established for heat trans-

fer, that it is considered valid to establish the mixing slope  $x$  experimentally by varying any one or two components

of the Reynolds number ( $D^2 N/\nu$ ), and then to depend on the relations for specifying the other components for scale-up.

When the mixing slope is less than 0.75, it is evident from Figure 14, that less power per unit volume is required for scale-up of dimensionally similar size systems. On the other hand, values of  $x$  above 0.75 require more power per unit volume as size is increased. It is of interest in this connection that only when the mixing slope is 0.75 will the scale-up be made on equal power per

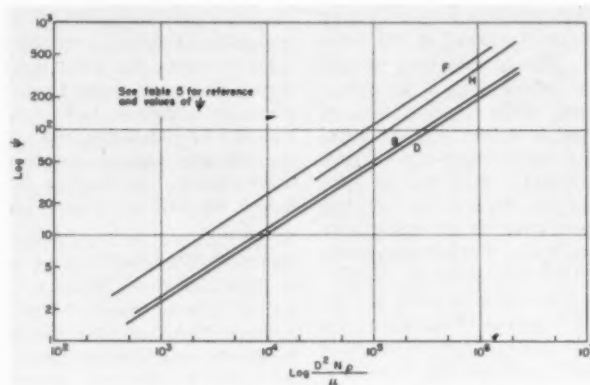


Fig. 13. Correlation of heat-transfer mixing data; see Table 5.

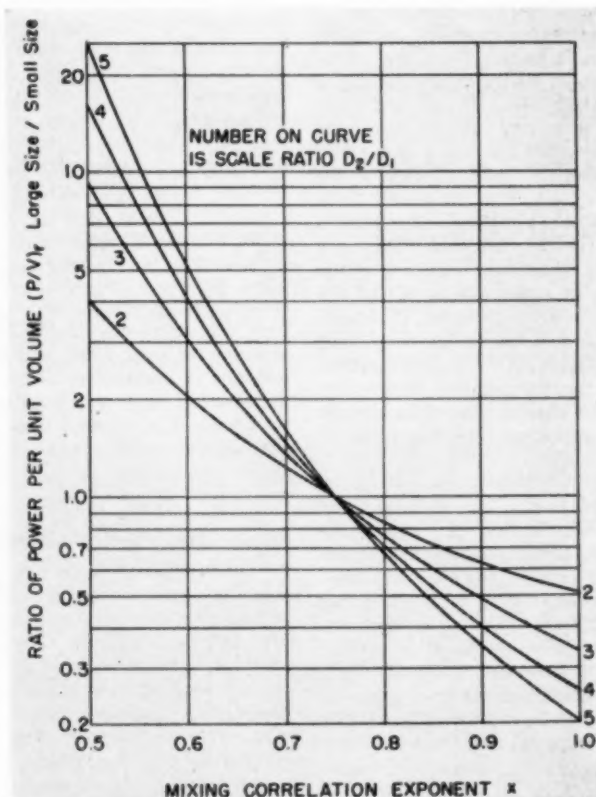


Fig. 14. Power, volume, mixing slope, scale-up relations.

unit volume; few mixing slopes were found to have this value. It follows that the majority of mixing operations are not scaled-up on the basis of equal power per unit volume for optimum results.

Further techniques for scale-up with relation to available data will be illustrated in terms of particular operations.

### Blending

Blending of miscible liquids, or mixing of gases with gases, is a mixing operation that can usually be related to quantity and velocity of flow and amount of liquid entrained in a flowing stream per unit of power. Data are available to determine flow from impellers (Equation (24)), and for the entrainment evolved (Equation (11)). The power required for a desired flow can be computed also from Equation (17). Scale-up can be made on simple similitude principles and on equal flow velocities at corresponding points (21). This is equivalent to scale-up based on equal rates of entrainment at corresponding points. It is believed that most blending operations are favored by high ratios of  $Q/H$ .

It has been shown that mixing hydrocarbons in large blending tanks can be performed by a side-entering propeller at approximately twice the efficiency (use of energy input), compared to mixing by use of jet action produced by an external low specific speed circulating pump (10). Table 4 gives a comparison. Data are given in the literature for power and other conditions necessary for blending of hydrocarbons in large

tanks by the use of jets produced by circulating pumps (12).

### Solid Suspensions

One particular criterion of solid-suspensions mixing operations is that velocities of flow at the most remote portions of the systems shall be equal to or greater than the terminal velocity of fall of the largest or heaviest particles. High velocities persisting over long distances usually require large flows, hence, high values of  $Q/H$  are ordinarily desired. Thus, relatively large diameter impellers ( $D/T = 0.4$  to  $0.6$ ) are often found to be advantageous for solid-suspension and dissolving problems. Scale-up can be made on equal flow velocities at corresponding points as in the case of blending.

### Heat Exchange

Many mixing operations involve heat ex-

TABLE 4.—RELATIVE PERFORMANCE FOR DIFFERENT MIXING METHODS FOR GASOLINE BLENDING IN A 100-FT. DIAMETER TANK.

Method of Mixing	Volume induced by propeller or jet flow per unit of power. Ratio.
Side entering propeller, 22-in. diam. ....	1.00
Jet, 6-in. in diameter ....	0.29
Jet, 2 in. in diameter ....	0.58
Circulating pump and line with 2-in. diam. jet ....	0.50

change, and when this is the dominant operation, the mixer is designed to give a desired rate coefficient  $h$ . Figure 13 shows data for heat exchange by various types (coils and vertical tubes) of heat-transfer surface, plotted in accordance with Equation (25). Table 5 gives pertinent information for use with Figure 13 and for jacket surface transfer not shown on the figure.

Data from various authors were used and recalculated to uniform basis of tube diameter



Fig. 15. Heat transfer with helical coil, baffles at tank wall, flat-blade turbine.

TABLE 5.—DATA FOR FIGURE 13

Item	Reference	Coil tube jacket	$\psi$	Tank Configuration	Slope $X$ of correlation line	Value of $\psi$ at $N_{Re}$ of 10	Value of $K$ for Equation (17)
A	Brown, Scott and Toyne (4)	Jacket	$\left(\frac{hT}{k}\right)\left(\frac{\mu_s}{\mu}\right)^{0.14} / \left(\frac{c\mu}{k}\right)^{0.25}$	Jacketed cast iron hemispherical bottom vessel Propeller—no baffles $T/D = 2.5$ U-Type impeller—no baffles. $T/D = 1.05$	0.67	27.8	...
B	Chilton, Drew and	Coil	$\left(\frac{hd}{k}\right)\left(\frac{\mu_s}{\mu}\right)^{0.14} / \left(\frac{c\mu}{k}\right)^{0.25}$	Helical coil, 9.6 in. diam. $\frac{1}{2}$ -in. tubing in 1 ft. diam. tank. Flat paddle, $T/D = 1.66$ close to bottom	0.62	50.0	1.7
C	Jebens (5)	Jacket	Tank diameter $T$ substituted for $d$ in value above	Liquid depth equal to tank diam. No baffles. $T/d = 24$	0.67	800.0	...
D	Cummings and	Coil	Same as for Chilton, Drew, and Jebens	Helical coil, 18-in. diam. 1-in. tubing in a 24-in. diam. tank.	0.62	46.0	1.2
E	West (7)	Jacket	Same as for Chilton, Drew, and Jebens	2 curved blade turbines. No baffles. $T/D = 2.5$ ; $T/d = 30$	0.67	890.0	for one 2.2 for two
F	Dunlap and Rushton (8)	Vertical tubes	$\left(\frac{hd}{k}\right) / \left(\frac{c\mu}{k}\right)^{0.25} \left(\frac{\mu}{\mu_s}\right)^{0.14}$	4 vertical tube baffles, $1\frac{1}{2}$ -in. tubes. One flat blade turbine. $T/D = 3$ Turbine position one-half liquid depth. $T/d = 25.3$	0.65	110.0	4.4
G	Rushton, Lichtman and Mahony (25)	Vertical tubes	Same as for Dunlap and Rushton	4 vertical tube baffles, 1-in. tubes. One flat blade turbine. $T/D = 3$ ; $T/d = 37.0$	0.90	68.5	4.6
H	Mixing Equipment Co. Tentative Data	Coil	Same as for Dunlap and Rushton	Helical coil 34-in. diam. $1\frac{1}{2}$ -in. tube in 4-ft. diam. tank. One flat blade turbine, 4 baffles each $\frac{1}{12} T$ . $T/D = 3$ Turbine position $\frac{1}{3}$ liquid depth. $T/D = 27.5$ . Figure 15	0.67	80.0	6.0

for the Nusselt group. Unless data are thus presented on an identical basis, the correlations are likely to be misleading. When they are on the same basis, the vertical distance between lines on this logarithmic plot shows differences in fundamental characteristics of the various systems. Curve *H* is a tentative one from continuing work on helical coil heat transfer (Fig. 15) at the research laboratories of Mixing Equipment Co.

The particular combination of coil, impeller, and baffle positions gives higher coefficients (proportional to the ordinate) at the same Reynolds number than other helical coil impeller arrangements heretofore reported. In the vertical tube arrangements, the tubes act both as heat-transfer surfaces and as baffles (8). This provides good mixing action by preventing swirl and vortexing, and allows large power inputs. If swirling is allowed (helical coil without baffles), high coefficients can be obtained because of high velocities, but power inputs cannot be as high as when swirling is eliminated. In final analysis, however, comparisons should be made on coefficients at the same power input. Power data for flat-blade turbines, propellers, and paddles are in the literature (24, 14) for the cases when baffles are used and when they are not used. Values of *K* for use in Equation (17) for the various impellers and configurations for which heat-transfer data are available, are given in the last column of Table 5, so that power can be computed for the various setups referred to. This allows comparisons to be made on equal power inputs. Values of *K* for the data on flat-blade turbines in items *F*, *G*, and *H* are exact, but the values for the other impellers, in items *B*, *C*, *D*, and *E* are estimated because the authors did not give power data.

The effect of a helical coil in a tank without vertical baffles, results in impeller power requirements less than those given by values of *K* for baffled conditions (Table 1), but greater than those for unbaffled impellers (24). Furthermore, the values of *K* with swirling present are a function of Reynolds number; hence, Equation (17) is only approximately applicable in this case. Nevertheless, to compare data in the literature on heat transfer where power data are not given, there is no choice but to make the best estimates possible so that power can be estimated. The *K* values in Table 5 for use in Equation (17) for items *B*, *C*, *D* and *E* are considered to be conservative (on the low side); those for *F*, *G*, and *H* are exact.

#### Mixing of Immiscible Liquids; Extraction

Extraction between two immiscible liquids is a commonplace operation often carried out by a series of mixers and settlers. Work is now in progress to establish relations between drop size and mixing, and on settling and coalescence of drops formed by rotating impellers. Here, the importance of the fluid mechanics of the system is even more complicated than in simple blending, and heat-transfer operations. Preliminary results indicate that drop formation and extraction therefrom are dominated by turbulence, and that low ratios of *Q/H* are favorable. It is suggested that scale-up of mixers for extraction be

based on relations like Equation (26), whereby the mixing slope *x* can be found and used as shown in Figure 14.

Continuous countercurrent-flow extraction columns using mixing impellers to form drops and to cause forced convection in the continuous phase are used commercially. Recently, data have been published for the performance of a multistage continuous flow liquid-liquid contacting column using flat-blade turbine mixers like

rotation. The picture at the right shows the impellers in motion; drops are circulating in the compartments, and the interface where coalescence occurs is shown above the top mixing compartment. Stage efficiencies, based on approach to equilibrium in each compartment, of more than 80 per cent have been measured for a 6-in. diam. glass column containing eight compartments, at throughputs of 4,400 lb./sq.ft. (hr.). Scale-up of these columns is being made

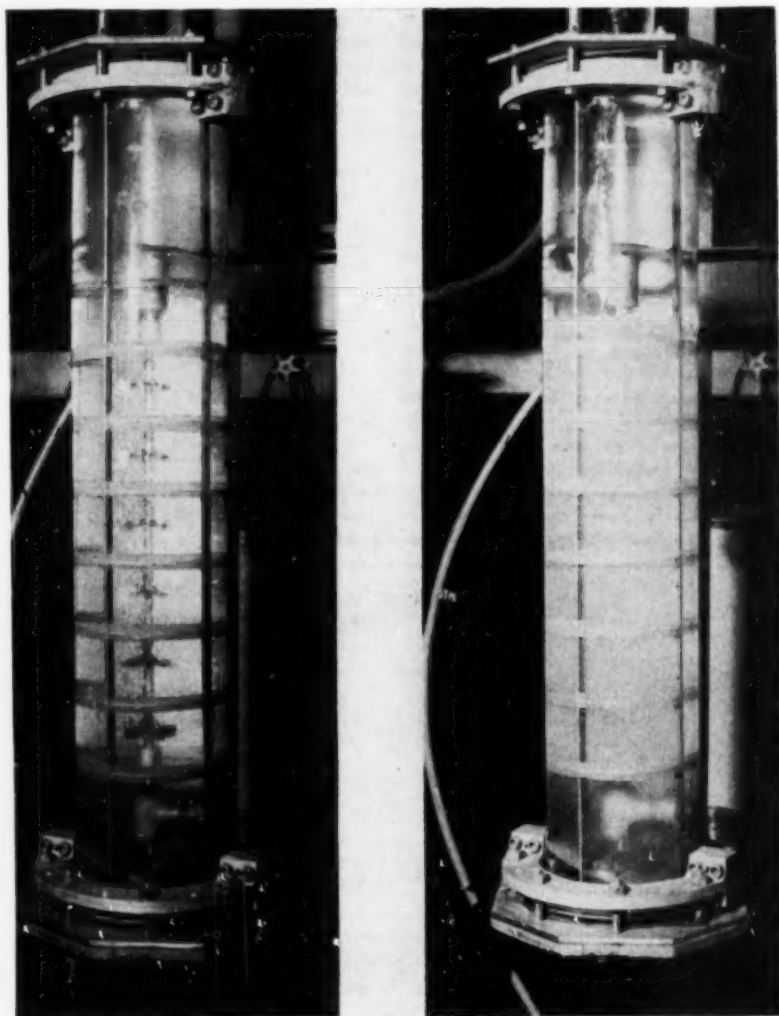


Fig. 16. Liquid-liquid extraction column with flat-blade turbines, baffles, and horizontal compartment plates.

that of Figure 6 (16). Such a column is shown in the photographs of Figure 16. Vertical baffles can be seen on the side wall of the cylinder, so that liquid motion is like the pattern shown in Figure 5. Horizontal discs can be seen, which serve to compartmentize the flow and minimize interstage mixing. Drops are formed by the impeller stream action, and turbulence in the streams flowing in each compartment provides the forced convection to maximize the mass-transfer rate coefficient. The picture at the left of Figure 16 shows a light phase liquid rising through a heavier continuous phase, without impeller

on the basis of test data from batch operations to determine flooding rates, optimum *Q/H* values, and mixing slopes from Equation (26).

Data are also available for a similar-type column to that of Figure 16, except that packed sections are used between mixing compartments (28). Scale-up data are not in the literature for this type column. Data for both these systems are compared with other forms of countercurrent extraction columns (16).

#### Gas-Liquid Contacting

Gas absorptions and stripping operations are affected by mixing. If the principal resistance



TABLE 6.

	Laboratory	Portable	Permanent Mounting					
			Light Duty			Heavy Duty		
			Top Entering		Side Entering	Top Entering		Side Entering
			Open	Closed		Open	Closed	
Motor mounting integral with mixer .....	×	×	×	×	×	×	×	×
Adaptable to all types of electric motor enclosures .....	×	×	×	×	×	×	×	×
Adaptable to all types of drive methods; electrical, air, hydraulic, steam .....	×	×	×	×	×	×	×	×
Availability of machinable alloys for all parts in contact with liquids .....	×	×	×	×	×	×	×	×
Auxiliary impeller shaft support .....	×	×	×	×	×			
Independent impeller shaft support, flexibly coupled ..						×	×	×
Ease of replacing and adjusting impeller shaft length ..	×	×						
Provision for universal mounting and positioning .....	×	×						
Integral construction of impeller shaft, stuffing box and tank mounting .....				×	×		×	×
Integral construction of mixer drive, stuffing box, and tank attachment .....			×			×		
Provision for repacking stuffing box below liquid level ..								×
Provision for variable speed drive .....	×	×				×	×	×
Convenient adaptability to different fixed speeds .....						×	×	

to mass-transfer rate is in the gas film, then the principal effect of the mixer is to form small bubbles, and thus to extend the transfer surface. Also, if a flow pattern as in Figure 5 is used, the drops will be circulated in the liquid and they will remain in contact with liquid for a longer time than if there were no circulation. If the principal resistance is in the liquid film, then the action is the same as just described, and in addition, the turbulence in the continuous phase will affect the mass-transfer rate coefficient.

Sparging of gas into liquids is widely practiced; the resulting mixing motion is surprisingly unsatisfactory, and all such operations encountered so far have been greatly enhanced by

application of mixers, with flow patterns as shown in Figure 5. Data are being published on the steam-stripping of lard, using a flat-blade turbine and vertical-tube baffles arranged as shown in Figure 17 (30). In this operation, with a single turbine, the results show rates of steam-stripping from 30 to 60% greater than were achieved by sparging without mechanical mixing. Figure 17 is a design used for hydrogenation operations. Solid catalysts can, of course, be suspended at the same time that gases are being dispersed.

Data are also available for mixers used for penicillin and other antibiotic production (1), and are in terms of antibiotic production, air flow rates, and various power inputs for flat-blade turbines. Results are reported for several sizes of equipment, and show that power per unit volume can be kept constant on scale-up, but the  $D/T$  ratio was *not* held constant. Data are also available for an air oxidation reaction, wherein a mass-transfer coefficient is related to power per unit volume (6) using "vaned-disc" and flat-paddle impellers. In this connection it should be noted that radial-flow impellers having discs like that in Figure 5 will prevent by-passing of gas up the impeller shaft—a position where minimum linear velocities exist.

From a mechanics standpoint, studies have been made on the interaction of gas flow rate, liquid viscosity, power input, and turbine position on the holdup and contact time between gas and liquid (13). The contact time can be related to absorption coefficient, and to over-all mass-transfer coefficient and results. In general, low values of  $Q/H$  are favorable to high-transfer rates, but, of course, flow must be sufficient to achieve high velocities so that the gas can be dispersed to all parts of the tank. For

this reason, baffles at the side wall of the tank are preferable to those which are close to the impeller, for the same power input. Scale-up has been successfully achieved on the basis of equal contact time per foot of depth of liquid.

It should be noted that an impeller running in liquid without gas will require more power than when running at the same speed with gas in the liquid. The principal cause of this effect is the change in the average fluid density (Equation (17)). In fact, unless there is a decrease in power demand when gas is added to the liquid, it is evidence that the mixer is not effectively distributing small bubbles of gas through the liquid. This power decrease with gas addition depends on gas rate, position of gas inlet, and impeller shape and size (13). Such data are essential for proper sizing of mixers.

The literature here referred to does not cover a number of articles on gas-liquid mixing wherein conditions are far from the best practice. Articles on biological processes have appeared giving performance data on particular processes using unconventional impellers and arrangements, without giving power and other data essential to quantitative evaluation of the work. For complete references to such information, and for all references to publications on mixing, see (22), which lists yearly review articles with complete bibliography.

#### Continuous Flow Systems

Mixing in continuous and series flow operations has been studied, and equations are available to determine the effect of transient conditions encountered in starting such systems, in the effect of by-pass, and the effect of the increment of energy brought into the system by the kinetic energy of the feed streams (9, 15).

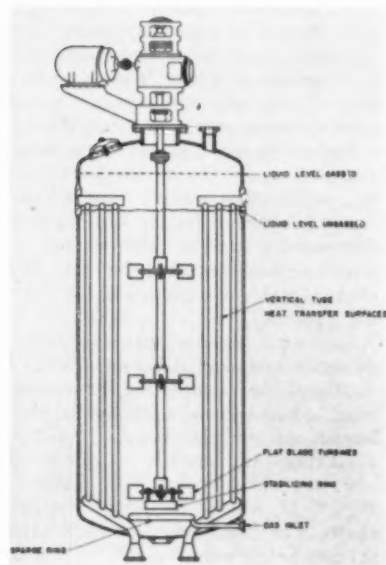


Fig. 17. Arrangement for gas-liquid operations with vertical-tube heat transfer, multiple flat-blade turbines, stabilizer ring under lowest turbine.

### Equipment for Liquid Mixing

Modern mixing equipment is markedly different in mechanical detail from that of twenty-five years ago. Accordingly, a brief discussion of equipment will be useful.

The basic problem underlying the design of all classes of mixers is to provide adequate support for the mixer shaft, and at the same time protect the driving mechanism from the mixer-shaft loads. Table 6 summarizes the important features desirable in the design and construction of liquid mixers (3, 23).

In the design and selection of fluid mixing equipment for any application the question of the amount of power to be applied and the speed at which the mixer should run must be considered. For a given amount of power, the higher the impeller speed the lower is the cost of the mixer, because the torque is an important factor determining the size and cost of the drive assembly. Laboratory mixers commonly range in power up to 1/20 hp., with output speeds from nearly zero to 1,800 rev./min. Some special laboratory mixers have speeds as high as 15,000 rev./min. Since laboratory mixers are used to obtain data for extrapolation to larger-size equipment, it is most important that the impellers used should be scale models of the larger ones (31).

Portable mixers generally range in size from fractional to 3 hp.; they are designed for use in open tanks, and are clamped to the tank shell. They are used on tanks up to 3,000-gal. capacity. Direct-drive units usually run at 3600, 1750, or 1150 rev./min., or at variable speed. Gear-drive units run at about 420 rev./min., or at variable speed.

Light-duty permanently mounted mixers are designed to take advantage of the service conditions under which they are applied so as to make an economical compromise with basic requirements of mixer design (23). They normally use propellers and employ the basic drive assembly of portable mixers, modified for permanent mounting to the tank. They range in size from fractional to 3 hp. and are used on tanks up to 3,000-gal. capacity. Tanks may be open or closed.

Light-duty, side-entering mixers are made in sizes up to 25 hp., but their use is giving way to heavy-duty designs because the majority of side-entering-mixer applications involve relatively large volume tanks where high rates of flow from the impeller are desirable. They are frequently designed to operate at 420 rev./min.

Heavy-duty permanently mounted mixers are generally used where the mixer must operate continuously, or nearly so, and where the service conditions are severe. Because of the variety

of impellers and blading used, no convenient and simple classification of these mixers as to impeller speed can be made. Heavy-duty mixers are made with all forms of driving means, but side-entering mixers are not often equipped with a variable-speed drive.

Heavy-duty mixers differ fundamentally in design and construction from light-duty mixers. They generally should employ independent mounting for the mixer shaft, connected by a flexible

Mechanical seals are being used increasingly in the stuffing box in heavy-duty mixers. Accurate alignment of the components is important, and integral construction of the mixer is essential. Wherever mechanical seals are used, the construction should provide for replacing the seal with packing for emergency operation (3).

Heavy-duty side-entering mixers are made in capacities of 1 to 50 hp. One or more units may be mounted on tanks

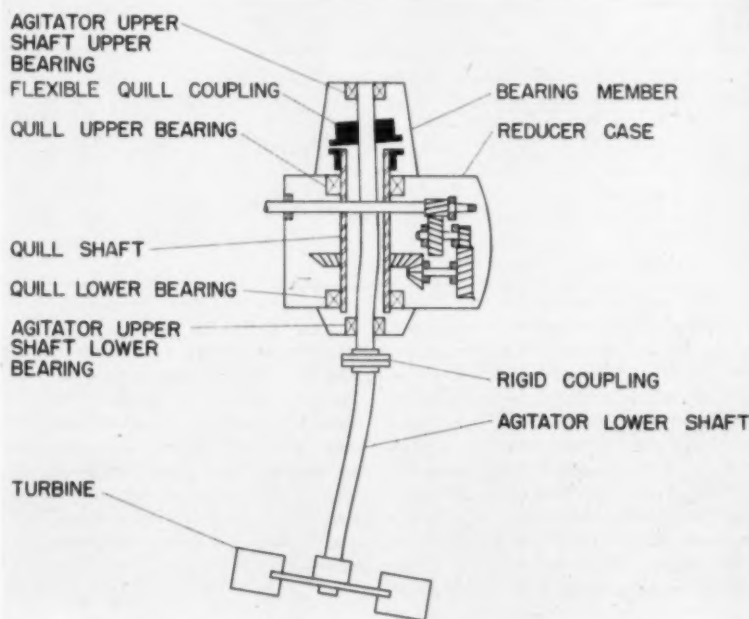


Fig. 18. Mechanical features of a modern top entering mixer.

coupling, thus protecting the speed-reduction gearing.

Heavy-duty top-entering mixers are made in capacities up to 500 hp. In general, they are designed for speeds between 45 and 200 rev./min. At these speeds, radial-flow impellers are ordinarily used. Because of their size and weight, and mountings required, they are placed with the shaft vertical and in the center of the tank.

It is desirable for the agitator shaft to be mounted independently of the speed reducer and coupled to it by means of a flexible coupling to assure complete protection for the gearing. Figure 18 shows an illustrative diagram of an assembly of a heavy-duty top-entering, closed-tank mixer which has independent mounting for the upper agitator shaft.

This arrangement provides the desired protection for the speed reducer from vibration, shock, and deflection. This particular illustration shows a speed reducer with a low-speed spiral bevel-gear set, helical gears for the high-speed elements, and a change-gear set which permits changing the mixer speed by selecting change gears of the desired ratio.

up to 1,000,000- (and more) gal. capacity. Nearly all heavy-duty, side-entering mixers are designed for 420 rev./min. propeller speed. They are built with the desirable features of the top-entering units and in addition, there is a shutoff collar and gasket on the mixer shaft, inboard of the stuffing-box assembly, permitting a seal-off from the tank contents when the mixer is stopped so that packing can be removed and replaced without emptying the tank. Mechanical seals are used as with top-entering units.

Care must be exercised in the design of shafts and impellers so that critical rotational shaft speeds are not encountered. Shaft whip is a function of shaft length and weight, impeller position, shaft speed, and liquid level. The stabilizer ring shown below the turbine in Figure 17 will permit long overhung shafts to be used safely even while liquid is being withdrawn from a vessel during mixer operation. Very long shafts may require a steady bearing at the bottom.

### Notation

Any consistent set of units may be used; some

are given here for illustration in foot, pound, second, degrees Fahrenheit, and mole units.

A = area  
 $c$  = heat capacity of liquid; also, concentration  
 $d$  = diameter of tube, for dimension parameter in Nusselt number  
 $D$  = impeller diameter, ft.  
 $D_c$  = diffusivity  
 $D_o$  = jet diameter at origin  
 $g$  = gravity constant  
 $g_F$  = gravity conversion factor  
 $h$  = film coefficient of heat transfer  
 $H$  = head, ft.  
 $k$  = thermal conductivity of liquid  
 $k_L$  = liquid film mass-transfer coefficient  
 $k$  = a constant  
 $l$  = mixing length, eddy scale, ft.  
 $L$  = a length, ft.  
 $N$  = impeller speed, rev./sec.  
 $N_P$  = power number  
 $N_{Re}$  = Reynolds number  
 $p$  = pressure; also, exponent of Prandtl group  
 $P$  = power, ft. lb./sec.  
 $Q$  = flow rate, lb./sec. or cu.ft./sec.  
 $Q_e$  = entrained flow rate  
 $s$  = exponent of Schmidt group  
 $T$  = tank diameter, also time  
 $v$  = velocity, instantaneous, vectorial, ft./sec.  
 $\bar{v}$  = velocity, average, vectorial  
 $v'$  = velocity fluctuation,  $v' = v - \bar{v}$   
 $V$  = volume  
 $W$  = width of impeller blade  
 $x$  = slope of correlating line, mixing slope  
 $X$  = distance from jet origin  
 $\propto$  = proportional to  
 $\gamma$  = specific weight, lb. force/cu.ft.  
 $\epsilon$  = kinematic eddy viscosity,  $\eta/\rho$   
 $\eta$  = eddy viscosity  
 $\mu$  = dynamic viscosity  
 $\mu_T$  = dynamic viscosity at mean film temperature  
 $\mu_s$  = dynamic viscosity at temperature of solid surface  
 $\nu$  = kinematic viscosity,  $\mu/\rho$ , sq.ft./sec.  
 $\phi$  = a function, a group of dimensionless units  
 $\rho$  = density, lb. mass/cu.ft.  
 $\tau$  = shear stress, lb. force/sq.ft.  
 $\psi$  = a function, a group of dimensionless units  
 subscript 1 refers to condition 1  
 subscript 2 refers to condition 2  
 subscript  $r$  indicates ratio  
 subscripts  $x, y, z$  refer to directions in the  $x, y, z$  axes, respectively  
 superscript bar indicates average  
 prime indicates fluctuation condition

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#### Discussion

H. C. Ries (Tufts College, Medford, Mass.): In one section you stated that  $v'_x$  was proportional to  $v'_y$  and also proportional to  $v'_z$ . Is it not true that the only requirement is that there be a relationship between these three quantities of such a nature that the laws of conservation of momentum and conservation of mass are satisfied, and that only in special cases can there be a proportionality between these three quantities which does remain constant in time?

J. H. Rushton: I intended to show that there is a definite interrelationship between the fluctuations in each direction  $x, y$ , and  $z$ ; the exact relationship must be determined experimentally.

H. C. Ries: If one considers the root mean square values of the fluctuations, one finds certain proportionalities which do remain constant in the special cases of isotropic turbulence, homogeneous turbulence, etc.

In the momentum transport equation shown in one of the figures, the pressure fluctuation was given as  $\rho v'^2$ . Is this correct, or should it be a fraction of this value?

J. H. Rushton: I believe that the Equation (4) is correct. (See (17, 18).)

H. C. Ries: You mentioned boundary layer and form separation as two methods of turbulence generation. I think that these are not two distinct methods but that the form-separation method is actually a boundary-layer phenomenon where vorticity is created in a boundary layer of the body.

In your discussion of jets, you seem to indicate that the mixing occurs in the region between the two streams, the stationary or slowly moving secondary fluid and the jet. Actually the maximum value of eddy viscosity occurs at the edge of the jet only at the nozzle. Further downstream the maximum is at some point between the axis and the edge of the jet; eventually, the maximum reaches the axis and from there on the entire cross section of the jet is taking part in the mixing.

If the initial turbulence of the jet is increased, the spread of the jet is materially influenced. Conceivably, therefore, the mixing rates could be markedly increased by putting a screen at the nozzle or just upstream of the nozzle.

J. H. Rushton: In presenting Figure 8 I emphasized the entrainment into the jet. The actual text states that turbulence spreads toward the center of the stream and also into the quiet fluid.

Your comment about the effect of jet spread as a function of initial turbulence is well taken; several of our graduate students have been working on this problem during the past year, and we hope soon to have data on this point.

(Presented at A.I.Ch.E. Chicago, Ill., Meeting)

# CHEMICAL RESISTANT CEMENT REFERENCE SHEET

RAYMOND B. SEYMOUR and ROBERT H. STEINER

The Atlas Mineral Products Co., Mertztown, Pa.

**BLEACH-RESISTANT CEMENT:** An infusible, room-temperature-setting plastic material consisting of a liquid resin and a finely divided inert filler. The two components are supplied in separate containers and are mixed on the job just before use.

**APPLICATION AND REMARKS:** Bleach-resistant cement mortar is prepared by mixing approximately five parts by weight of the powder with two parts of the liquid resin. This mortar is used for joining acid-proof brick or tile which serve as chemical resistant linings in steel or concrete chemical vessels, such as bleach tanks, towers and floors. The mortar can also be used for casting process equipment, such as tanks, ducts, fittings

and pipe. Cements of this type exhibit excellent resistance to hypochlorite bleach solutions at temperatures as high as 110° F. and at a pH range of 1 to 11. It is one of the few materials that has been found satisfactory for chlorine dioxide service. This cement is also resistant to sulfuric acid in concentrations up to 60%, nitric acid up to 10%, chromic acid up to 10% and hydrochloric and phosphoric acid in all concentrations. Resistance to mild alkalis is good but the cement is attacked fairly rapidly in solutions having a pH greater than 11. Bleach-resistant mor-

tar will set completely in contact with and adhere tenaciously to Portland cement and metallic surfaces without the use of special primers.

**WORKABILITY:** Bleach-resistant cement mortar can be readily trowelled onto the brick or tile. A working life of 30 to 60 min. and a complete set in 2 to 4 hr. at 65 to 85° F. are typical for this type of cement.

**MACHINABILITY:** Objects cast from bleach-resistant cement can be sawed, turned, drilled and tapped with care on ordinary metal-working machines. Pieces can be cemented together using the same mortar.

## A TYPICAL BLEACH-RESISTANT CEMENT

### MECHANICAL AND PHYSICAL PROPERTIES

Tensile strength, lb./sq.in. @ 77° F.	1200
Impact strength, notch, Izod, ft.-lb./in.	0.4
Flexural strength, lb./sq.in. @ 77° F.	6000
Compressive strength, lb./sq.in. @ 77° F.	11000
Adhesion to wire-cut brick surfaces, lb./sq.in.	> 400
Adhesion to sand-blasted steel surfaces, lb./sq.in.	400
Specific gravity	2.0

### TEMPERATURE

**LIMITATIONS:** Bleach-resistant cements can be used continuously at temperatures up to 250° F.

## CORROSION RESISTANCE

ACIDS	C	H		C	H		C	H
Acetic, 10%	E	F	Ferric chloride, nitrate, sulfate	E	E	Green liquor	N	N
Acetic, glacial	N	N	Nickel chloride, nitrate, sulfate	E	E	White liquor	N	N
Benzene, sulfonic, 10%	E	E	Stannic chloride	E	E	Sulfite liquor	E	F
Benzoin	E	E	Zinc chloride, nitrate, sulfate	E	E	Hypochlorite bleach	E	F
Boric	E	E				Chlorine dioxide, acid solutions	E	G
Butyric, 100%	E	N	<b>ALKALINE SALTS</b>			Chlorine dioxide, neutral solutions	E	G
Chloroacetic, 10%	E	F	Barium sulfide	G	P	Chlorine dioxide, alkaline to pH 11	G	F
Chromic, 5%	E	P	Sodium bicarbonate	E	P			
Chromic, 10%	E	P	Sodium carbonate	G	P	<b>PHOTOGRAPHIC INDUSTRY</b>		
Chromic, 20%	E	P	Sodium sulfide	G	P	Developers	E	E
Citric	E	E	Trisodium phosphate	G	P	General use	E	E
Fatty acids	E	N				Silver nitrate	E	E
Fluoboric	E	N	<b>NEUTRAL SALTS</b>					
Formic, 90%	E	N	Calcium chloride, nitrate, sulfate	E	E	<b>FERTILIZER INDUSTRY</b>		
Hydrobromic	E	E	Magnesium chloride, nitrate, sulfate	E	E	General use	E	E
Hydrochloric	E	E	Potassium chloride, nitrate, sulfate	E	E			
Hydrocyanic	E	N	Sodium chloride, nitrate, sulfate	E	E	<b>STEEL INDUSTRY</b>		
Hydrofluoric	E	N				Sulfuric acid pickling	E	E
Hypochlorous	E	E	<b>GASES</b>			Hydrochloric acid pickling	E	E
Lactic	E	E	Chlorine, dry	G	N	H <sub>2</sub> SO <sub>4</sub> -HNO <sub>3</sub> acid pickling	F	P
Maleic, 25%	E	E	Chlorine, wet	G	E	<b>TEXTILE INDUSTRY</b>		
Nitric, 5%	E	E	Sulfur dioxide, dry	E	E	General use	E	E
Nitric, 20%	E	E	Sulfur dioxide, wet	E	E	Hypochlorite bleach	E	F
Oleic	E	E				Chlorine dioxide, acid solutions	E	G
Oxalic	E	E	<b>ORGANIC MATERIALS</b>			Chlorine dioxide, neutral solutions	E	G
Perchloric	E	E	Acetone	N	N	Chlorine dioxide, alkaline to pH 11	G	F
Phosphoric	E	E	Alcohol, methyl, ethyl	E	N	<b>FOOD INDUSTRY</b>		
Picric	E	E	Aniline	E	N	General use	E	E
Stearic	E	E	Benzene	E	N	Breweries	E	E
Sulfuric, 50%	E	G	Carbon tetrachloride	E	N	Dairies	E	E
Sulfuric, 80%	E	N	Chloroform	E	N			
Oleum	N	N	Ethyl acetate	P	N	<b>MISCELLANEOUS INDUSTRIES</b>		
Mixed acids, 57% H <sub>2</sub> SO <sub>4</sub> , 28% HNO <sub>3</sub>	N	N	Ethylene chloride	N	N	Plating	E	E
			Formaldehyde, 37%	E	N	Petroleum	E	F
			Phenol, 5%	E	E	Tanning	E	F
			Refinery crudes	E	E	Oil and soap	G	F
			Trichloroethylene	N	N	Water and sewer	E	E
<b>ALKALIES</b>								
Ammonium hydroxide	F	N	<b>PAPER MILL APPLICATIONS</b>					
Calcium hydroxide	N	N	Kraft liquor	N	N			
Potassium hydroxide	N	N	Black liquor	N	N			
Sodium hydroxide	N	N						
<b>ACID SALTS</b>								
Alum or aluminum sulfate	E	E						
Ammonium chloride, nitrate, sulfate	E	E						
Copper chloride, nitrate, sulfate	E	E						

### RATINGS:

E—No attack.  
G—Appreciable no attack.  
F—Some attack but usable in some instances.  
P—Attacked—not recommended.

N—Rapidly attacked.  
C—Cold—70° F.  
H—Hot—200° F. or boiling point of test solution.

**No. 21**



## WATER-COOLED BELT CONVEYOR SOLIDIFIES MOLTEN SULFUR

Seymour Schwartz

S. Schwartz & Associates, Consultants, New York City

**A** NEW approach to the problem of taking sulfur from the liquid to the solid state in a form that is easily handled was successfully demonstrated in Mexico recently. A water-borne stainless steel belt conveyor converts recovered molten sulfur to glass-like chips, about  $\frac{5}{16}$  of an inch thick, at the sulfur plant of Petroleos Mexicanos in Poza Rica, Mexico. The solidifier belt has been in use for almost two years.

Normally sulfur is brought out of the ground in the liquid state, and pumped into forms to harden. When the forms are filled the sides are raised, or leap-frogged, and additional sulfur pumped on top until a monolithic block is formed measuring about 30 ft. wide by 60 or more ft. long by 30-45 ft. high. When shipment is to be made the pile, or "vat," is drilled, blasted and crushed to 2 to 3-in. lumps before it can be loaded.

In the Pemex plant a free-flowing, dustless sulfur flake about 3 in. on a side is produced on a continuous belt-solidifier which eliminates labor and materials, and avoids blasting hazards.

### Description of Sulfur Solidifier

The sulfur solidifier consists of a horizontal flexible stainless steel conveyor belt 32 in. wide by 184 ft. long between pulley centers, and employs a patented water-bed cooling feature.\* The belt is made of a special Swedish steel imported from Sandviken, Sweden, and rolls around two pulleys 40 in. in diam. The upper strand of the belt at the feed end rides on twelve, 12-ft. long shallow water bed tanks, which are slightly narrower than the width of the belt. Water at about 85° F. is fed into the bottom of these tanks and overflows the sides into collecting troughs. Part of the water is sewered and part recycled with fresh make-up. Since 144 ft. of belting ride over these tanks from which water overflows, this length of belting is buoyed or "floated" on the surface of the cooling water.

In order to maintain a pool of sulfur

on the belt, the sides are fitted with  $\frac{5}{8}$ -in. rubber edging over the entire length of the belt. The unit is driven by a 5 hp. motor and two,  $\frac{3}{4}$  hp. motors, drive the cooling water pumps. Belt speed can be varied from 10 to 80 ft./min.

### OPERATION OF SOLIDIFIER

Molten sulfur at about 260° F. is fed to a constant head tank by a bleed-off from the plant circulation system. The sulfur overflows to an open shallow trough which straddles the belt. The overflow weir of the trough provides a uniform feed of molten sulfur across the entire width of the belt at a rate consistent with plant production and belt speed. While carried along on the top of the belt the sulfur undergoes solidification owing to cooling of the belt from beneath by the water, and by heat loss to the atmosphere.

By the time the sulfur reaches the discharge end it has hardened and cooled, and readily unpeels from the belt. A doctor blade, which is usually necessary only at the start-up, and a simple breaker, chop the continuous

sheet of sulfur into small, glass-smooth chips. These chips, which vary from  $\frac{1}{4}$  to  $\frac{3}{8}$  of an inch in thickness and about 3 in. on a side, are picked up by an inclined rubber belt and dumped onto a storage pad or else discharged into the boot of a bucket elevator which feeds a storage silo. Sulfur is loaded from this hopper and trucked either to Mexico City where it is converted into sulfuric acid or fertilizers, or else transported to Tuxpam to be sold in export.

### SOLIDIFIER CAPACITY

The belt was designed to handle 150 tons of sulfur a day, which was in excess of the normal plant production. In tests to determine the capacity, though, a rate of 250 tons a day was attained. It was not possible to measure the ultimate capacity, but based on temperature profile measurements, it is probable that double the rate, about 500 tons a day, could be handled.

### PERFORMANCE DATA

An idea of the solidifier performance may be gained from the data on page 22.

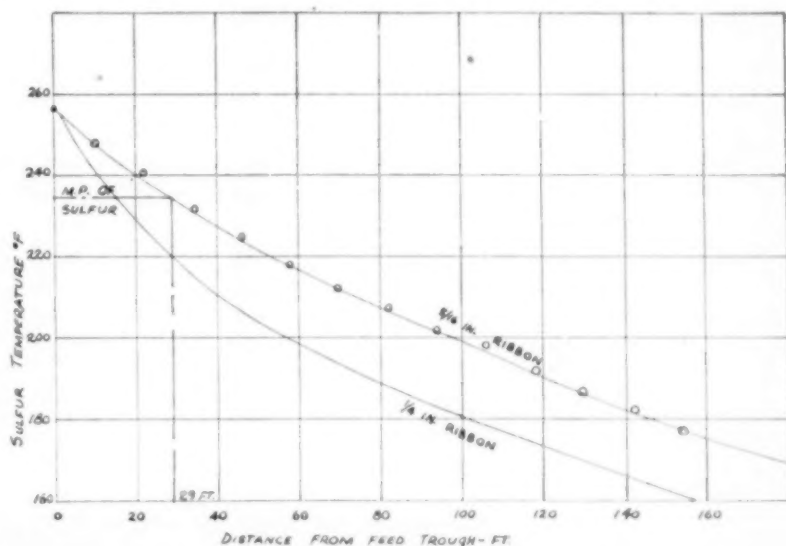


Fig. 1. Cooling rate of molten sulfur on Sandvik solidifier.

Conveyor designed and manufactured by the Sandvik Steel Corporation of New York City.

# LOW-TEMPERATURE DRYING OF GELATIN SPONGE

M. M. Harmon, Upjohn Company, Kalamazoo, Michigan

**V**aried production problems are the bête noire of the manufacturers of pharmaceutical products, and proper air conditioning and humidity control are two important tools in the solution of these problems. Air-conditioning requirements in controlling bleeding during surgery has always been one of medicine's major concerns.

Back in 1946, The Upjohn Co., Kalamazoo, Mich., developed a gelatin sponge for the control of bleeding during surgery called Gelfoam. The material is essentially a gelatin base, which is treated with a minute quantity of formalin, beaten to a foam, and dried in batch-type ovens for 72 hr. The resulting Gelfoam is a white, porous mass which, when dry, can be cut into any desired shape and, when moistened, immediately becomes absorbent and pliable, adhering quickly to a bleeding area.

The engineers confronted with the production problems of the company soon found that air moisture could play havoc with Gelfoam production, particu-

larly regarding the air supply to the low-temperature drying ovens. Excess moisture in the heated air resulted in a longer baking period, since the air would have less capacity for absorbing moisture from the gelatin mass. With a dry air supply, lower-drying temperatures can be employed to accomplish the baking—an important factor since the gelatin mass cannot be heated above a specific critical temperature without deleterious effects during the bake. Engineers soon determined that the problem called for a supply of dehumidified air to the drying ovens and after preliminary studies were finished, they installed in 1950 two Kathabar\* dehumidifying units to supply dry air to all ovens in the Upjohn operations including those for the Gelfoam bake. A total of 27,000 cu.ft./min. of dehumidified air is delivered by one 12,500 cu.ft./min. capacity and one 17,500 cu.ft./min. capacity chemical-absorbent-type unit.

\* Trade name of drying units of the Surface Combustion Corp.

During operation only 10% or less fresh make-up air at maximum conditions of 95° F. and 120 gr. of water per pound is used in the system, primarily to keep the ovens under a slight pressure. A preheat coil is situated in the fresh air line after the filter for winter operation. The make-up air and recirculated air from the ovens are mixed, filtered, and then passed through the dehumidifiers. Approximate conditions of this recirculated air are 95° F., 24 gr./lb. (10% R.H.).

Air enters the dehumidifiers with a moisture content of 37-43 gr./lb. and leaves at conditions of 14-17 gr./lb., which means a relative humidity of 7% or less at 90° F. Upon completing the dehumidifying pass, the conditioned air mixes with an additional supply of filtered recirculated air, increasing the temperature and grain content of the total air supply to roughly 79° F., 19 gr./lb. An after-heat coil is then employed to raise the air temperature to the 90° F. required delivery condition.

## Dehumidifying Equipment

The dehumidifying equipment consists of two sections, air washer and regenerator.

Air to be conditioned passes through an air washer to contact the lithium chloride-base absorbing solution. At the same time, both air and solution pass over cooling coils. The cooler the absorbent, the greater is its moisture-holding capacity. The cooling coils, therefore, control the temperature and, in turn, the moisture-retaining capacity of the absorbent, thereby dictating the amount of air drying to be done.

In addition, the air itself is cooled a certain amount in this action. Once the leaving air-moisture conditions are set, automatic controls regulate the quantity of coolant

(Continued on page 28)

TABLE 1.—AIR-CONDITIONING REQUIREMENTS FOR HYGROSCOPIC PROCESSING AREAS AT THE UPJOHN CO.

Process Room Space	Air Conditions		Hygroscopic Product	Effect of high humidity on product
	Temperature ° F.	Relative Humidity %		
Soluble Vitamin B filling room .....	85	10	Soluble Vitamin B	Caking in machinery
Alkaline effervescent compressing room .....	70	15	Effervescent salts	Corrode and pit rotary tablet machine die faces
			Alkaline powders	Powder clings to die faces
			Penicillin powders	Tablet with absorbed moisture burst when coated
Vitamin tablet compressing room .....	85	10	Vitamin powders	Caking
Vitamin products mixing room .....	90	10	Vitamin powders	Product deterioration
Gelfoam drying ovens .....	90	9	Gelatin foam	Longer drying time
				Product deterioration
Hard gelatin capsule filling room .....	83	15	Vitamin powders	Caking in capsulating machines
Physics laboratory .....	76	30	Electron microscope	Corrosion of delicate equipment
			Photographic film	Longer film drying time
				Noncontrolled humidity affects experimental results
Misc. drying ovens .....	90	10	Miscellaneous	Longer drying time
Vitamin tablet coating pans .....	88	8	Vitamin tablets	Longer drying time
Finished coated tablet drying ovens .....	100	4	Coated tablets	Longer drying time
Pill coating and polishing pans .....	85	30	Compressed pills	Longer drying time
			Coating powder	Caking of powder in pans
			Vegetable gel	
Soft gelatin capsule drying ovens .....	90	10	Gelatin capsules	Longer drying time
Soft gelatin capsule sorting room .....	80	30	Gelatin capsules	Becomes sticky to handle
				Lose shape
Soft gelatin capsule capsulating room .....	80	30	Gelatin capsules	Cling to machinery and each other
				Lose shape
Soft gelatin capsule mixing room .....	78	17	Gelatin powder	Caking machinery

Chemical absorbent dehumidifiers treat all air where relative humidities less than 50% are maintained in this pharmaceutical plant.

# TYGON

the economical answer  
to  
expensive corrosion problems

Tygon is the generic name for a group of plastic compounds specifically designed to combat corrosion. Based on a series of selected polyvinyl resins, TYGON offers outstanding protection against both acids and alkalis plus oils, greases, water and most solvents, except esters, ketones and certain aromatic hydrocarbons. The various forms of TYGON available make its proper application a simple matter for many uses in many industries under many conditions.

## *As tubing*

TYGON PROVIDES SAFE TRANSMISSION FOR VIRTUALLY ANY LIQUID, GAS OR SEMI-SOLID

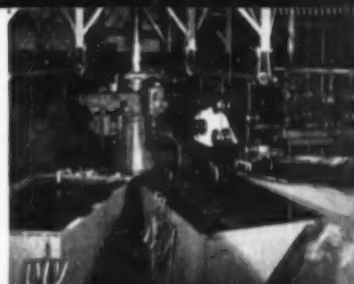
TYGON Tubing is widely used in both plant and laboratory. In the "lab," TYGON'S glass-like clarity, full flexibility, smooth surfaces, non-contaminating and non-oxidizing properties make it quicker, easier, safer and cheaper to use in the most intricate "set-ups" or with the most delicate solutions. In the plant, these same properties plus its light weight, high strength, excellent abrasion resistance and easy installation, give TYGON tremendous advantages over conventional piping. TYGON Tubing is available in six standard formulations, in clear or glossy black, with a wide range of physical, chemical and electrical properties. Sizes range from .12" I.D. to 2" I.D. Braided jacket reinforcement in fabric, plastic and stainless steel is also available for use with constant working pressures up to 300 psi.



## *As linings*

TYGON OFFERS HEAVY DUTY PROTECTION TO EQUIPMENT OF PRACTICALLY ANY SIZE OR SHAPE

TYGON press-polished sheeting in thicknesses of 3/32" or 3/16" makes it ideally suited to the protection of tanks, tank cars, diffusional towers, vats, reactors, bins, hoppers, troughs, pipe and other processing equipment against a wide range of chemicals. Its unique resistance against oxidizing acids, oils, greases and certain solvents permits the use of TYGON in jobs other linings cannot handle. Its wear resistance assures long life with the most abrasive materials. Its flexibility permits close conformance to the most intricately shaped equipment. Its lack of the need for "curing" makes possible installations of virtually any size. TYGON, for lining work, is available in two standard compounds—TL 104 (Black) for general use and TL 104-A (White) where solution visibility is desired.



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TYGON PROVIDES POSITIVE, ENDURING SEALS FOR ALL TYPES OF PROCESSING EQUIPMENT

Die-cut, molded, or extruded, TYGON is the sure answer to tough gasketing jobs in chemical processing or general industrial equipment. Its chemical resistance, abrasion resistance, resilience, high strength, non-contaminating and non-oxidizing properties make it practical to use under a wide range of operating conditions. TYGON gaskets can be die-cut from calendered or press-polished sheeting (1/64" to 1/2" thick); can be molded in practically any size or shape; can be extruded as tubing, solid cord, strip, or channel in continuous lengths. A number of standard compounds are available.



## *As paint*

TYGON OFFERS EASILY APPLIED, LASTING PROTECTION AGAINST CORROSIVE FUMES AND SPILLAGE

As a paint, TYGON is primarily used to protect plant and equipment against corrosive fumes and spillage. It is also used against immersion in mild corrosives or to prevent contamination of delicate solution. TYGON Paint is easily applied and quick drying. Dry, its film is chemically resistant, tough, flexible, and smooth; resistant to cracking, chipping or crazing. There are two types of TYGON Paint available. TYGON "Series K" Paints do not require a primer and are used against mild corrosion. TYGON "Series TP" Paints are for use with primers under severe conditions of corrosion. TYGORUST, the "no-prep" vinyl primer is recommended for use under either type of TYGON PAINT on rusted metal—wet or dry.



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Write, today, for full information about this plastic of many uses.

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And United States Gasket Company engineering and fabricating experience has made the most of Teflon's outstanding mechanical properties—its resiliency, anti-hesion and anti-friction qualities—to adapt it to the operating requirements of all types of chemical equipment.

The "Tufclad"® chemical porcelain valve above for instance, made by the Lapp Insulator Co., Inc. of Le Roy, N.Y., utilizes a wedge-type Chemiseal Packing which effects a seal with extremely low gland pressure and friction load on spindle. This type packing is particularly suitable for ceramic valves, as well as glass-lined, Havg, Karbate and valves made of similar materials.

Write for catalog. For valve packing, request 810 series. For pump packing, request 711 series. For emergency bulk and extruded stuffing-box packing, request 620 series.

See Page 22

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GASKET  
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**FLUOROCARBON  
PRODUCTS DIVISION**  
CAMDEN 1, NEW JERSEY

Representatives in Principal  
Cities Throughout the World

## MOLTEN SULFUR

(Continued from page 19)

Sulfur feed rate	10.5 net tons/hr.
Sulfur feed temperature	258° F.
Sulfur discharge temperature	168° F.
Make-up cooling water temperature	92° F.
Discharge water temperature	105° F.
Water circulation rate (50% sewerage)	96 gal./min.
Belt speed	53 ft./min.
Average chip thickness	5/16 in.

The rate at which the sulfur was cooled while carried along on the water-borne conveyor was determined by placing a thermometer in the pool at the feed end and reading it as it moved along toward the discharge end.

Figure 1 shows the temperature profile along the solidifier, and was obtained by averaging the results of two tests at the same rate. It will be noted that the melting point of liquid sulfur, approximately 235° F., was reached at 29 ft. from the feed trough and the remainder of the water-cooled section, comprising 115 ft., merely cooled the solidified ribbon.

The cooling characteristic for a 1/4-in. thick ribbon of sulfur obtained on an experimental solidifier under different atmospheric conditions, is shown in Figure 1 for comparison.

### COSTS

For a solidifier belt, erected on the Texas Gulf Coast, the factory cost is estimated at \$25,000. Allowing for freight, erection, conveyor belts, etc., the total fixed capital cost is estimated at \$50,000. The cost of solidifying 240 tons a day of molten sulfur would be:

	Cost/Net Ton of Sulfur
Labor (half-time of one operator @ \$2.00/hr.)	.10
Maintenance (3% of fixed capital)	.02
Power (\$.01/kw.hr.)	.01
Cooling water (\$.10/M gal.)	.03
Depreciation (15%/year)	.09
Supplies, insurance, taxes, etc.	.04
	<b>\$ .29</b>

Viewed on an over-all basis, the use of the water-cooled sulfur solidifier represents a new low-cost solution to a conventional operation.

### Acknowledgment

The author expresses thanks to the A. G. McKee Co., Petroleos Mexicanos and Sandvik Steel Corp. for assistance in preparing this article.



## The De Nora Cells At MUSCLE SHOALS

The De Nora cells at the new Government-owned, Monsanto-operated chlorine plant, Muscle Shoals, Alabama, are eloquent testimony to chemical engineering progress.

Uniformly high quality GLC GRAPHITE ANODES are doing their share to help the electrolytic industry meet the ever-increasing civilian and defense demands for chlorine and caustic soda.

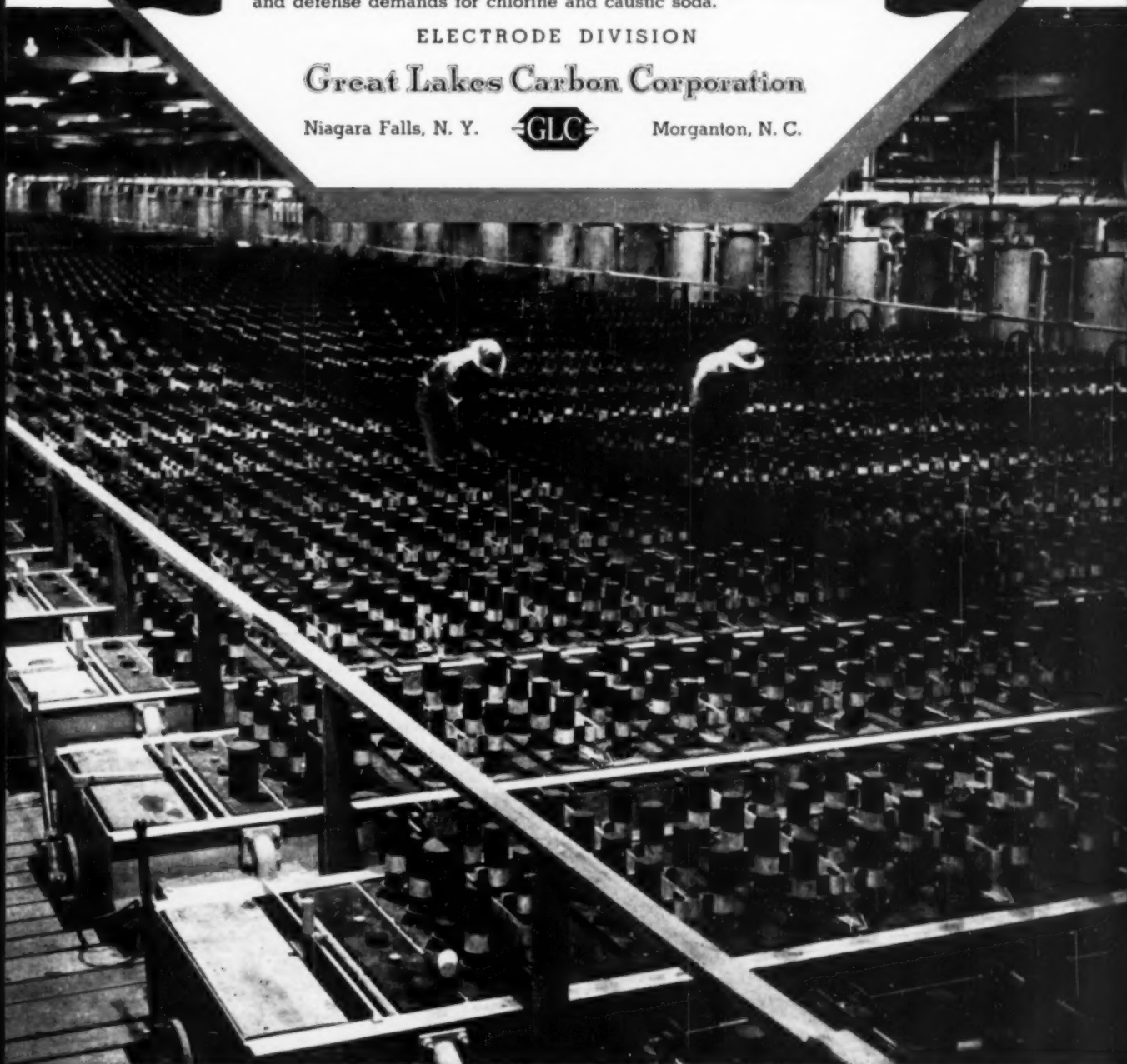
ELECTRODE DIVISION

Great Lakes Carbon Corporation

Niagara Falls, N. Y.



Morganton, N. C.



*Courtesy Monsanto Chemical Company*

### Graphite Anodes, Electrodes and Specialties

**Sales office:** Niagara Falls, N. Y.    **Other offices:** New York, N. Y., Chicago, Ill., Pittsburgh, Pa.

**Sales Agents:** J. B. Hayes, Birmingham, Ala., George O'Hara, Long Beach, Cal., Great Northern Carbon & Chemical Co. Ltd., Montreal, Canada.

## RECORD ENROLLMENT APPROACHED BY 1952 ENGINEERING STUDENTS

**T**he fourth largest class ever to enter the nation's engineering schools enrolled in 1952, according to a survey issued by the American Society for Engineering Education and based on a study by the U. S. Office of Education. Only in the years immediately following World War II—1946, 1947, and 1948—has the freshman class been larger. The percentage increase in new engineering students was more than twice the increase of all entering college students. The total engineering enrollment for 1952-1953 is 7.3% greater than that

for 1951-1952, in contrast with an 0.8% decline in total male enrollments for the same period.

Despite this promise of a brighter future, the present need for engineers, as noted in a recent report of the Engineers Joint Council, remains unfilled. The 1953 class, which will probably total less than 25,000, will not spread around the minimum of 40,000 current engineering openings. Next year's class will be even smaller, about 20,000. Of the present 45,854 newly enrolled students only 29,000 are expected to finish, and a

proportion of these, it appears now, will go directly into military service instead of into industry.

Reasons for the increase in engineering enrollments were given by the report as follows: "(1) the widely publicized need for technical and scientific personnel and the relatively high rates of pay new engineering graduates are receiving, (2) the opportunity for military reserve training with attendant commissions upon graduation, and (3) the fact that postponement of military

*(Continued on page 42)*

ENGINEERING COLLEGE ENROLMENTS  
(U. S. only)

### UNDERGRADUATE ENROLLMENT

Year	Freshman	Sophomore	Junior	Senior	5th Year	Part Time and Evening	Total	No. of First Degrees
1940	33,175	24,242	30,120	16,310	985	14,079	108,911	11,358 (1939-40)
1941	27,507	21,615	24,482	12,369	1,946	12,180	90,099	10,177 (1940-41)
1942	27,507	21,615	24,482	12,369	1,946	12,180	90,099	10,177 (1940-41)
1943	47,672	52,949	59,945	45,695	1,924	17,932	226,117	27,460 (1942-43)
1944	36,508	35,648	41,695	50,991	2,326	13,478	180,646	41,793 (1943-44)
1945	29,394	27,242	30,957	37,707	3,150	14,504	142,954	48,160 (1944-45)
1946	25,147	24,408	24,757	27,820	2,946	12,395	127,493	37,964 (1945-46)
1947	45,854	26,636	22,369	23,453	2,563	17,295	138,170	27,155 (1946-47)

### GRADUATE ENROLLMENT

Year	Master's Degrees and Other Pre-Doctoral Degrees				Doctor's Degrees					
	Full Time	Part Time	Evening	Total	Master's and Other Pre-Doctoral Degrees	Full Time	Part Time	Evening	Total	Doctor's Degrees
1940	2,003	980	1,599	4,582	1,318 (1939-40)	404	179	41	624	108 (1939-40)
1947	5,465	3,663	3,515	12,643	3,090 (1946-47)	704	784	79	1,567	127 (1946-47)
1948	6,138	2,348	4,882	13,368	4,303 (1947-48)	1,046	569	454	2,069	252 (1947-48)
1949*	6,277	4,056	7,426	15,079	4,783 (1948-49)	1,593	793	155	2,541	417 (1948-49)
1950*	8,150		4,745	15,575	4,865 (1949-50)		2,342	453	2,795	492 (1949-50)
1951*	6,878		9,574	16,452	5,134 (1950-51)		2,419	456	2,875	586 (1950-51)
1952*	7,422		9,996	17,418	4,132 (1951-52)		2,261	669	2,930	586 (1951-52)

Total college enrollment in U. S. ....	1,490,000	2,333,000	2,410,000	2,456,000	2,297,000	2,116,000	2,148,000
Engineering enrollment in U. S. ....	113,497	244,390	241,554	198,266*	161,324*	147,694*	158,518*
Per cent engineering to total .....	7.6%	10.5%	10.0%	8.0%*	7.0%*	7.0%*	7.4%*

\* Includes only E.C.P.D. accredited institutions.

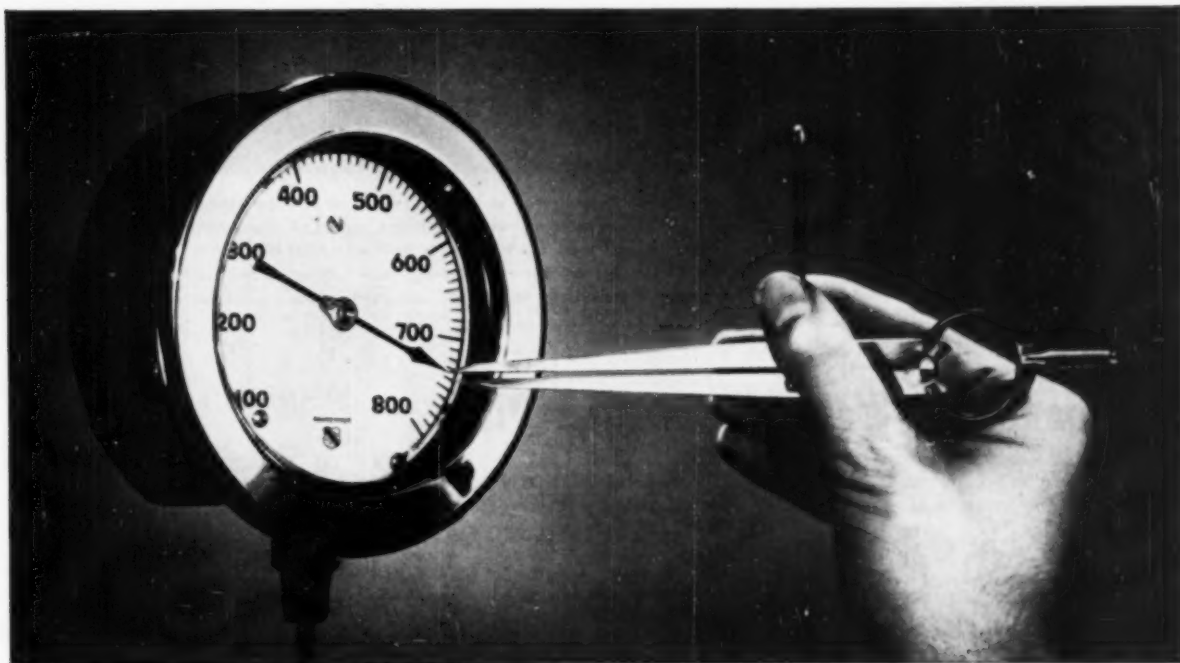
### UNDERGRADUATE AND GRADUATE ENGINEERING ENROLLMENT BY CURRICULA, OCTOBER, 1952

Engineering curricula	Graduate enrollment												
	Undergraduate enrollment			Master's-degree enrollment				Doctorate enrollment					
	No. of schools	Total enrolled	No. of first degrees, 1951-52	No. of schools	Day students	Evening students	Total	No. of master's degrees, 1951-52	Day students	Evening students	Total	No. of doctorates, 1951-52	
Schools accredited by ECPD:													
Aeronautical	47	4,103	694	38	368	361	729	221	111	31	142	24	
Agricultural	32	1,230	334	25	140	...	140	70	14	..	14	5	
Architectural	30	3,253	736	11	29	...	29	17	..	..	..	..	
Ceramic	13	466	156	65	156	...	155	38	..	..	..	8	
Chemical	107	12,704	2,743	82	775	999	1,774	540	467	76	543	159	
Civil	137	20,283	4,917	94	931	917	1,848	571	166	82	248	43	
Electrical	135	26,696	5,876	96	1,686	3,575	5,261	990	567	269	836	121	
Engineering Mechanics	2	30	20	25	140	101	241	59	86	26	112	25	
Engineering Physics	31	1,347	288	17	129	166	295	90	43	14	57	29	
General Engineering	24	3,685	614	11	208	61	269	54	55	..	55	5	
Geological	23	1,071	261	13	93	...	93	17	9	..	9	4	
Industrial <sup>1</sup>	59	5,073	1,573	39	484	1,027	1,511	265	26	33	59	6	
Mechanical	132	29,335	6,823	91	1,201	1,869	3,070	627	271	72	343	64	
Metallurgical	46	2,262	578	41	265	294	559	134	219	43	262	53	
Mining	30	1,113	371	19	48	...	48	30	7	..	7	3	
Naval Arch. and Marine	3	192	57	3	22	...	22	6	..	..	..	..	
Petroleum	22	3,249	642	17	171	21	192	74	5	..	5	8	
Sanitary	8	131	32	14	76	10	86	30	..	..	30	7	
Textile	5	585	98	3	23	...	23	10	..	..	..	..	
Unclassified	92	20,124	45	14	53	343	396	22	12	..	12	..	
Other	30	1,238	297	29	276	248	524	116	125	23	148	23	
Total E.C.P.D.	149	138,170	27,155	116	7,183	9,992	17,175	4,005	2,261	669	2,930	586	
Other U. S. Schools	44	17,910	3,131	2	6	115	121	9	..	..	..	..	
All U. S. Schools	193	156,080	30,286	118	7,189	10,107	17,296	4,014	2,261	669	2,930	586	

<sup>1</sup> Includes administrative engineering, management engineering, etc.

# PRECISION CONTROL FOR PROCESS HEAT

with DOWTHERM, heat can be controlled within fractions  
of a degree at temperatures up to 750°F.



Dowtherm<sup>®</sup>, the modern heat transfer medium, maintains high temperatures within a fraction of a degree by simple pressure regulation . . . and gives this precise control uniformly over the entire process heating surface.

A liquid material used as a vapor heating medium in an entirely closed system, Dowtherm operates at high temperature, low pressure, and extends the advantages of steam-type heating to a much higher range of temperatures.

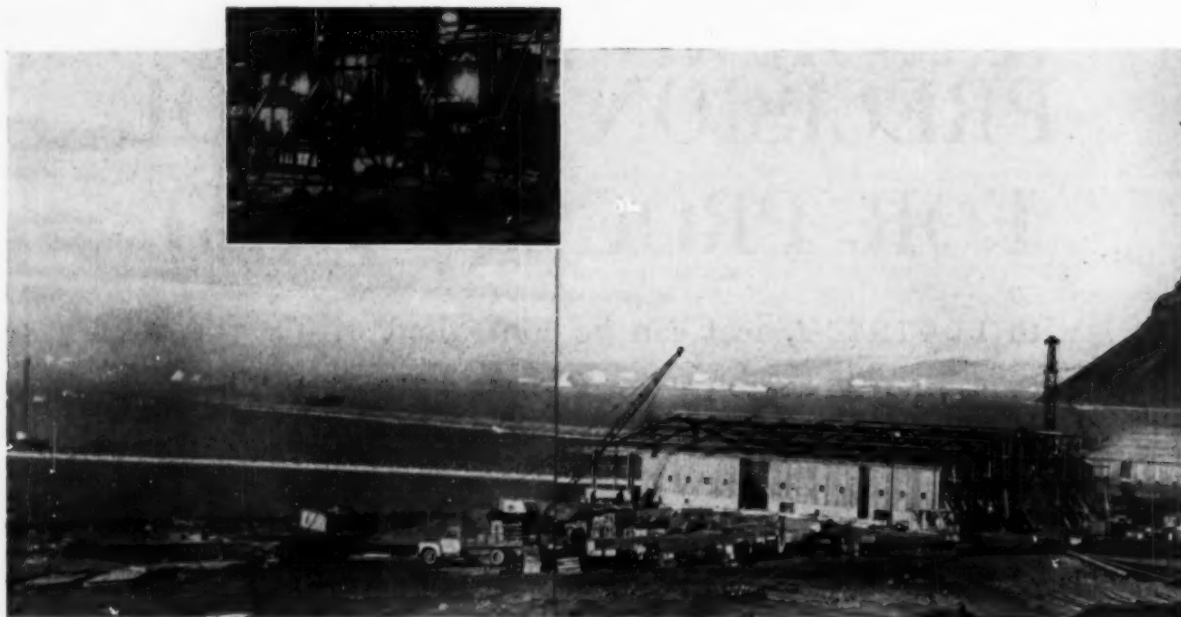
Dowtherm was created by the Dow research

team for the chemical, petroleum, paint, food and other process industries—has helped to increase production and even made possible new products.

Countless installations in all industries have thoroughly proved the efficiency and cost reducing potentialities of Dowtherm. For complete information on these benefits and how they apply to your industry, write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Department DO 3-1A.

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Inset is a view of the interior of the plant, also showing the jacketed supply pipe carrying the main salt-water line and a steam pipe to prevent freezing of the water while it is being conducted to the plant.

Panoramic view of construction of the U. S. Air Force base distillation plant at Astro Point, Thule, Greenland. Because of the permanently frozen ground at Thule, heavy buildings are constructed with underlying air ducts and with double walls to prevent interior heat from thawing the ground. The buildings house the distillation units, boilers, and Diesel electric generators. In the left foreground can be seen the salt-water supply pipe, which extends over a causeway.

## Giant Salt-Water Distillation Plant

**T**he largest salt-water distillation system in the world was recently installed by the U. S. Army Corps of Engineers on the U. S. Air Force base at Astro Point, Thule, Greenland, 910 miles from the North Pole. The distillation units, of the thermocompression type, yield fresh water of extreme purity by means of salt-water evaporators, motor-driven vapor compressors, heat exchangers, and distillate pumps.

The salt-water evaporator consists of a vertical nest of tubes containing salt water, surrounded by a shell into which the steam for heating is carried. The steam heats the salt-water to boiling, and the distillate, compressed to approximately 4 lb./sq.in., is drawn off by the vapor compressor. The compressed vapor is directed into the outer shell, where it combines with the steam originally supplied for heating and gives up heat to the tube which assists in evaporating the incoming salt water. The condensate collects in the bottom of the shell, and it is drawn off by the distillate pump.

The conservation of heat, via the exchanger, is an especially important function in the Arctic. Incoming cold salt water for the distillation unit is pre-

heated by the hot brine waste and the hot distilled water leaving the unit.

After the unit has operated for a short time, according to the Engineers Corps, the only outside source of steam required is one that will afford sufficient heat to make up for radiation losses and residual heat carried away by the brine waste. Radiation losses are reduced to a minimum in these Arctic temperatures by use of efficient lagging.

Approximately every two weeks it is necessary to descale the tubes in the evaporator. This is done by circulating acid through the system for several hours.

Salt water for the units is drawn from under the ice by means of deep-well pumps installed on a rock causeway extending into the bay. Insulated salt-water mains extending along the causeway to the distillation plant have a small steam tracer enclosed alongside the main line to prevent freezing of the water in transit.

The units were designed and installed under the supervision of the Northeast District, Corps of Engineers, U. S. Army. Metcalf & Eddy, Boston, were the engineers, and housing for the units was constructed by the Luria Engineering Co., Bethlehem, Pa.

## STANDARD FOR VINYL FILM

A Recommended Commercial Standard for general purpose vinyl plastic film is being circulated to the industry and the public for written acceptance by the Commodity Standards Division of the U. S. Department of Commerce. It is based on a proposal by the Society of the Plastics Industry and was modified to meet the desires of the majority at an industry conference on Nov. 18, 1952.

The Recommended Commercial Standard covers methods of test and requirements of general purpose plain or embossed vinyl plastic film to insure satisfactory products for consumer use. The requirements and methods of test specify thickness tolerances, yield per roll, width tolerances, shrinkage at elevated temperatures, contamination, appearance, cracking, tensile properties, tear resistance, volatility of plasticizer, water extraction, low-temperature impact and flammability. Suggested forms for declaring compliance with the standard and an identifying hallmark are included.

Mimeographed copies of the Recommended Commercial Standard, which is identified as TS-5165, may be obtained as long as the supply lasts by writing to F. W. Reynolds, Commodity Standards Division, U. S. Department of Commerce, Washington 25, D. C.



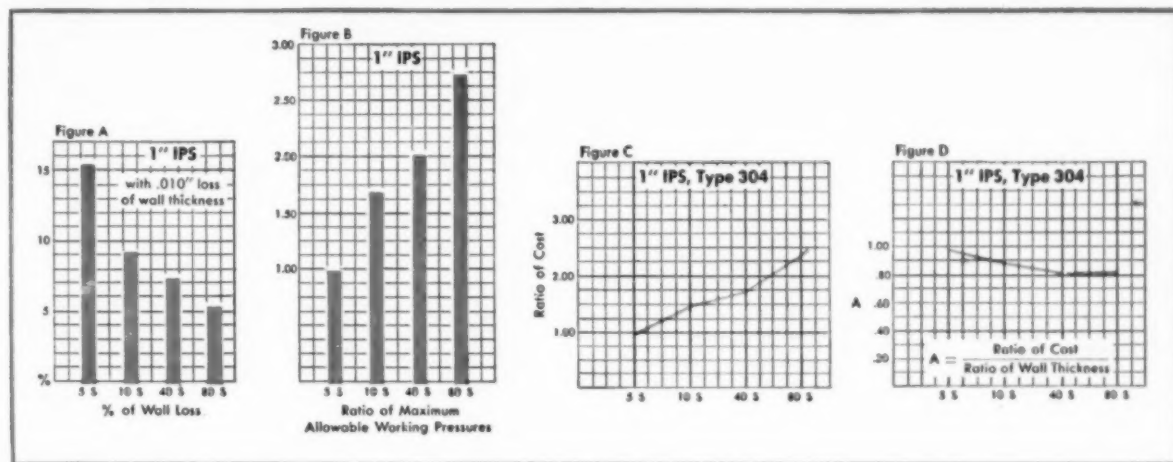
take a closer look at

# Stainless STEEL PIPE SIZE Schedules



Don't be "penny wise and pound foolish" where stainless steel piping is concerned. The most economical choice does not always imply the least initial cost as working pressure, methods of joining, installation costs and allowance for loss by corrosion

are critical factors. This is particularly true where costs resulting from failures in service—replacement of equipment and lost production due to down time—may exceed the initial cost of the piping.



## CORROSION RESISTANCE

For long service life it is advisable to allow for some loss in wall thickness where stainless piping is employed to combat severe corrosion. As shown in Figure A even a small loss means an appreciable percentage loss of wall thickness in the lighter weight schedules.

## WORKING PRESSURES

As shown in Figure B, the heavier pipe schedules permit higher working pressures, thus perhaps permitting the use of smaller diameter piping, or offering greater flexibility for subsequent changes in operational procedures.

## COSTS

Although the lighter schedules cost less, as shown in Figure C, you actually get more for your money with the heavier schedules because the ratio of increase in cost is less than the ratio of increase of wall thickness (Figure D).

## 1" IPS



While various types of fittings are available for the lighter weight pipe schedules, they should be examined carefully as to initial cost, installation cost, working pressure permitted and ease of adaptation to existing lines.

Whatever your stainless piping problems, Mr. Tubes—your B&W Tube representative—can provide valuable assistance. Consult him for advice on the stainless piping or tubing that will afford optimum cost-life ratio under your service conditions.

## Methods of Joining & Installation Costs

From the standpoints of economy and ease of installation, it is extremely important that attention be given to methods of joining, fittings, etc. because:

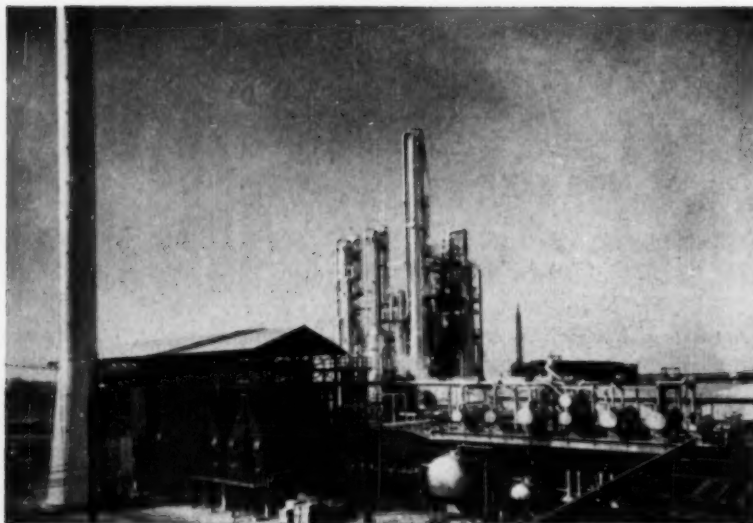
1. Schedule 40 IPS is the lightest weight pipe specifically designed for threading.
2. Fittings which provide a good thread and also afford structural strength at the joint are not commercially available for lighter weight pipe.
3. Field welding of thin wall pipe is difficult.
4. Misalignment of connections can cause high installation costs.



TA-1709 (G)

## THE BABCOCK & WILCOX COMPANY TUBULAR PRODUCTS DIVISION

Beaver Falls, Pa.—Seamless Tubing; Welded Stainless Steel Tubing  
Alliance, Ohio—Welded Carbon Steel Tubing



Gulf Oil Corp.'s formal entrance into the petrochemical field was made when this ethylene plant was put into operation at the company's refinery at Port Arthur, Texas. The unit's entire annual output of 2½ billion cu.ft. of ethylene gas is being delivered to five chemical plants on the Gulf Coast.

## GULF EXPANDS PETROCHEMICAL OUTPUT

A new plant to produce 2½ billion cu. ft. of ethylene gas annually, to be used extensively as a raw material in making chemicals, was opened last month by Gulf Oil Corp. at Port Arthur, Texas. Direct-connection pipelines to Koppers Company, Port Arthur; Ethyl Corporation, Houston; Du Pont Co., Orange; Monsanto Chemical Co., Texas City; and Allied Chemical and Dye Corp., Orange, absorb the entire output.

Under consideration, the company announces, are plans for a second ethylene plant to double present production and an ethylene oxide and an ethylene glycol plant. Only a portion of the capacity of the second ethylene plant, now being studied, would be offered for sale, the report stated. The remainder would be used to produce 40,000,000 lb. of ethylene oxide annually, which would be converted into 5,500,000 gal. of ethylene glycol, to be used in the manufacture of antifreeze.

The existing plant comprises a series of fractionating towers for separating ethylene, ethane, and other hydrocarbons from refinery gases and a series of cracking furnaces for converting the ethane to ethylene. Extensive instrumentation permits a large degree of operation from a central control room.

If plans are carried out, the second ethylene plant together with its related ethylene oxide and ethylene glycol facilities would be erected adjacent to the existing unit. These installations would use direct oxidation to produce ethylene oxide from the ethylene and conventional methods for producing ethylene glycol for antifreeze.

## BIO-ENGINEERING SYMPOSIUM AT TERRE HAUTE

A Bio-Engineering Symposium, sponsored by the chemical engineering department, Rose Polytechnic Institute, in cooperation with the Terre Haute Section, A.I.Ch.E., will be held at Rose Polytechnic Institute, Terre Haute, Ind., on May 23. Its general purpose is to discuss and summarize current advances in the fermentation engineering field, concentrating especially on antibiotics. O. G. Wegrich is chairman of the symposium. Dr. Wegrich is currently the head of the microbiological pilot plant of Commercial Solvents Corporation of Terre Haute.

The technical program is as follows:

### Morning Sessions

**9:00—MICROORGANISMS—THE BASIS FOR AN INDUSTRY** by Ralph E. Bennett, University of Pennsylvania.

**10:00—THE FIELD OF BIO-ENGINEERING** by A. J. Schmitz, Chas. Pfizer & Co., Inc., Brooklyn, N. Y.

**11:00—PRINCIPLES OF INDUSTRIAL STERILIZATION** by R. K. Finn, University of Illinois.

### Afternoon Sessions

**2:00—APPLICATION OF FLUID MIXERS TO BIO-ENGINEERING PROCESSES** by J. Y. Oldshue, Mixing Equipment Co., Inc., Rochester, N. Y.

**3:00—INDUSTRIAL RECOVERY OF FERMENTATION PRODUCTS** by P. R. Greenman and A. R. Elliott, Commercial Solvents Corp., Terre Haute, Ind.

**4:00—FERMENTATION RATES AND PRODUCTIVITY; THEIR RELATION TO PROCESS CONDITIONS** by E. L. Gaden, Jr., Columbia University.

## GELATIN SPONGE

(Continued from page 20)

flow so as to effect continuous operation.

Intermittently, a small quantity of the moisture-laden absorbent passes automatically into the regenerator, where it flows over low-pressure steam coils. As the solution is heated, its moisture-retaining capacity is reduced, and excess water in solution is driven off and exhausted to the atmosphere by a scavenging air stream. The absorbent is then returned to the air washer for further dehumidifying passes. No manual controls are necessary in the entire operation once the equipment is started up.

Because of the need to maintain precise quality control in all of the Upjohn departments, 120 separate air-conditioning systems are in operation at Upjohn's new Portage Road plant. Seventy-five are for the manufacturing areas alone. Throughout the entire plant, conditioned air is supplied at a rate of more than 1,220,000 cu.ft./min.

Some of these systems are simple comfort-cooling units. Others are highly complex, with ultraviolet germicidal lamps, chemical absorbent dehumidifiers, and electrostatic precipitators combined with conventional air-cooling equipment.

### Dehumidifiers Supply Low Humidity Air

Three centrifugal refrigerating compressors, with a cooling effect equivalent to approximately 1050 tons/hr., provide the cooling for a central chilled-water system. This system provides a comfort atmosphere of 75° F. and 50% relative humidity in the principal manufacturing and office areas.

Relative humidities below the 50% level provided by the chilled-water system are necessary for efficient manufacture in numerous drug-processing areas. Table 1 conveniently sets forth the air conditions required for the majority of those spaces in which moisture-sensitive products are processed. In addition to the areas listed in the table, Upjohn supplies low dew-point air to its freeze dry room so as to avoid moisture condensation on available metal surfaces.

### Summary

The increased use of low-humidity air conditioning in pharmaceutical operations today is an important factor in reduced drug production costs. In the application described—dry air for low-temperature Gelfoam ovens—overly long baking periods with increased fuel costs and harm to the product because of high-temperature operation are both avoided. In all instances where high temperatures (more than 100° F.) are detrimental to the product, a low-humidity air supply to the oven is one satisfactory mode of operation.

(More News on page 30)

**Struthers  
Wells**

# KRYSTAL

**VACUUM  
CRYSTALLIZER  
FOR PRODUCING  
NON-CAKING,  
UNIFORM  
CRYSTALS**

Crystalline materials such as potassium chloride produced in the Krystal equipment illustrated are uniform in size, non-caking, dust free, and easily separated from mother liquor in filter or centrifuge.

Krystal crystallizers can be operated for long periods without shutdown time for cleaning. Thus, Krystal produces crystalline materials of highest quality with greatest economy.

Our crystallization engineers are available for consultation on your crystallization problems.

Write for Bulletin 50-A which describes the principles and applications of Krystal crystallizer equipment.

## KRYSTAL

*stands for quality  
throughout  
the world*



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Wells**

**STRUTHERS WELLS CORPORATION**

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Plants at Warren, Pa., and Titusville, Pa.  
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for *Low*  
**VACUUM PUMP  
 MAINTENANCE  
 COSTS and BETTER  
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*It's the*

**HILCO OIL RECLAIMER**

**VACUUM  
 for PUMP  
 USERS..**



**A** simple, economical and efficient method of restoring contaminated lubricating and sealing oil to the full value of **NEW OIL**. The HILCO will produce and maintain oil free of solids, gums, water and gases in a continuous, all-electric, automatic operation.

**Be SURE of clean oil in your  
 HIGH VACUUM PUMPS**



**HILCO  
 OIL RECLAIMER  
 SYSTEMS..**

• **WRITE FOR COMPLETE DETAILS  
 IN THE FREE BULLETIN**

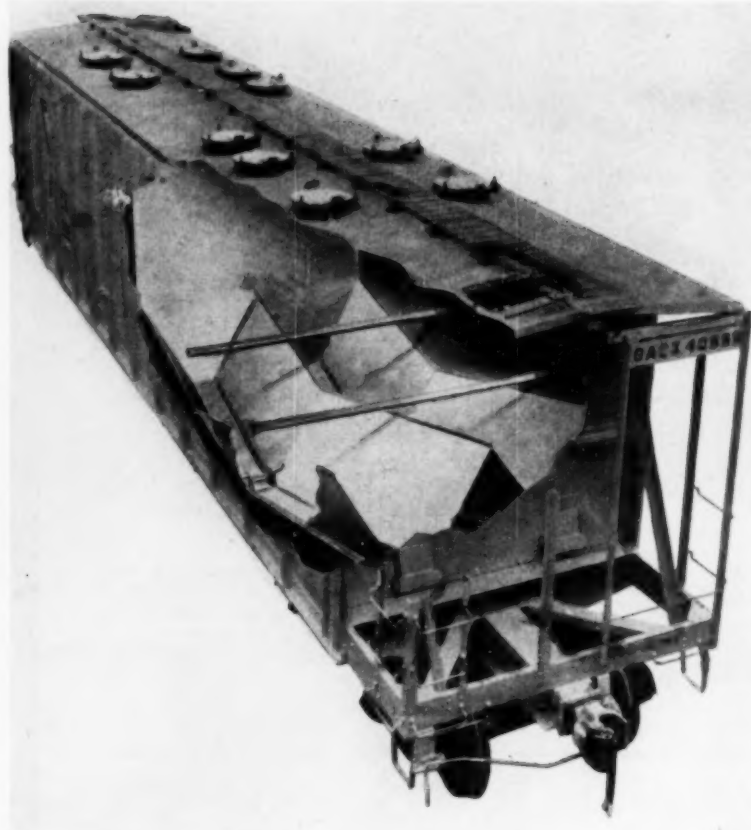
*Recommendations at no Obligations*

**THE HILLIARD  
 CORPORATION  
 • PURIFIER DIVISION •**

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**HILCO** • A Complete Line of Equipment  
 For Reclaiming, Filtering, Purifying  
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## NEW FREIGHT CAR FOR BULK MATERIALS

A new type of freight car which makes practical use of air to fluidize and slide bulk loads to exit ports and which will handle a wide range of dry powdered materials, such as feed stuffs, chemicals, starches, and similar commodities, was announced last month by William J. Stebler, executive vice president of General American Transportation Corp.

The new car, Mr. Stebler explained, was designed in collaboration with the Fuller Company of Catasauqua, Pa., and utilizes the Fuller Airslide. The essential part of the Airslide is a fabric of special design stretched over a U-shaped shallow steel channel. The channel below the fabric forms a plenum into which air is introduced at a pressure of approximately 1 lb./sq.in. and in varying quantities, depending upon the material transported. The Airslide slopes toward the center of the car, and as air is forced through the fabric, slowly permeating the commodity above the fabric, the lading is aerated and fluidized, causing it to flow to the unloading point.

Loading of the Airslide car is done through roof hatches. The lading may be moved from the car by either gravity

or pneumatics into any conventional conveying system. The only essential piece of equipment which the shipper requires, according to Mr. Stebler, is a small low-pressure blower, capable of delivering 200 cu.ft. or more of air per minute and costing approximately \$500 to \$600.

To ensure a minimum of product retention after unloading, the car features welded construction and 60-deg. slope sheets. The executive stated that the car can be built in sizes of 2,000, 2,600 and 3,600 cu.ft. The 2,600-cu.ft. car is expected to offer economical transportation of a variety of commodities having bulk densities in the neighborhood of 40 lb./cu.ft. This car is of particular interest, it was explained, because owing to the A.A.R. limitation of an 84-in. height of center of gravity above the rail, this is the first time that it has been possible to tailor a covered hopper car to a wide range of lading requirements.

In his talk Mr. Stebler envisioned savings in containers, dunnage and labor to shippers for whom bulk handling has not been considered practical.

*(More News on page 32)*



# A Superior Controller

## must be readily adaptable



### FIELD MOUNTED

THE FLEXIBILITY OF THE CONTROLLER TYPIFIES

## P-4 PNEUMATROL

The "building block" design and construction of Fischer & Porter P-4 Pneumatrol units provides the maximum in versatility of use. These design features permit ready change of a case mounted Pneumatrol into a field mounted controller by the mere addition of pre-built, basic elements. This unique feature of the P-4 assures minimum spare parts inventory and simplifies servicing.

The P-485 field mounted controller combines the best features of force and motion balance controllers by the unique application of paired bellows elements for precision, speed and permanence. It is the fastest field mounted controller and yet

has completely stable high frequency response. P-4 Pneumatrol units are extremely compact in size, simple in operation and completely corrosion resistant.

The plug-in type companion manifold has been just as thoroughly designed as the P-4 and includes built-in cut-off relay, automatic output cut-off below 1 psi setting pressure, positive self-sealing ports with unusually large air passages to prevent degrading the control response.

F&P P-4 Pneumatrol flow controllers are extremely versatile in their application. Complete information is yours for the asking. Write today!

## FISCHER & PORTER CO.

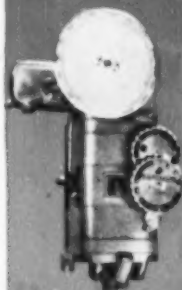
Ⓒ 1955

150 County Line Road, Hatboro, Penna.



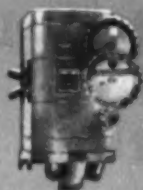
**P-485  
FIELD  
MOUNTED  
CONTROLLER**

(Proportional, Reset, Derivative) with plug-in air connections. Mounting plate includes shutoff relay and air check feature.



**P-475  
FLOW  
RATIO  
CONTROLLER**

for wide range flow ratio requirements. Optional construction provides VARIABLE PNEUMATIC SET CONTROL.



**P-45  
CASE  
MOUNTED  
CONTROLLER**

Proportional, Automatic Reset, Derivative Action obtained by installing snap-in resistor assembly below proportional dial.



**P-43M  
CASE  
MOUNTED  
CONTROLLER**

Wide band proportional with manual reset.



**P-42  
CASE  
MOUNTED  
CONTROLLER**

Narrow band proportional.

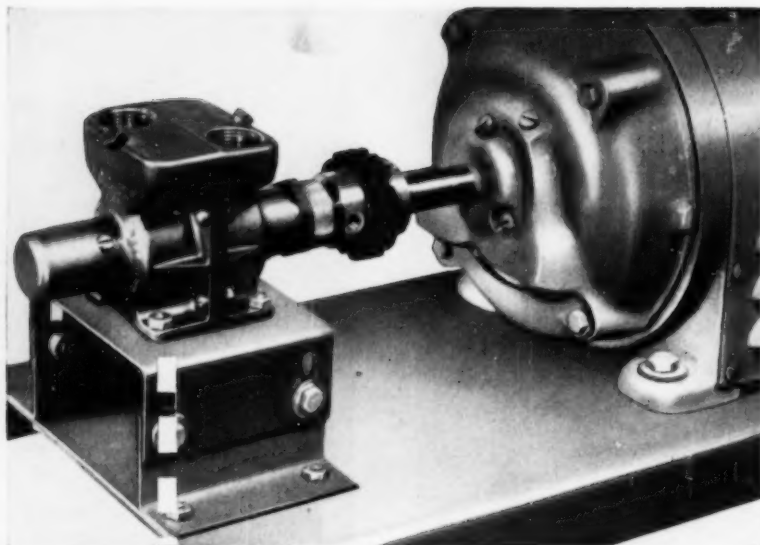


**P-41  
CASE  
MOUNTED  
CONTROLLER**

On-off action.



Temperature compensated pneumatic transmitter—a special form of the P-4 Pneumatrol utilizing many features.



## The Universal Pump for Lab. and Pilot Plant

- If it's 10 g.p.m. or less you need at pressures up to 70 psi, the Eco All-Chem is the pump you want.

Handling 70 percent of all corrosive chemicals, including such hazardous fluids as nitric acid and hydrogen peroxide—Eco All-Chem Pumps with their All-Teflon and stainless steel construction will handle most, if not all your requirements. Simplify pump selection. Cut pump and repair part inventories.

Select this "universal" chemical pump that is the outgrowth of nuclear, guided missile and other classified installation requirements.

- *Outstanding Characteristics:* Positive displacement with two opposed axially oscillating impellers equivalent to duplex piston operation. Minimum pulsation, air-entrainment, non-foaming, lowest corrosion rate of any stainless steel pump, highest suction lift over widest temperature and viscosity range, self-priming on non-volatile liquids. Applicable to direct motor drive at 1750 RPM and to all other standard driving methods.

ECO ENGINEERING COMPANY  
12 New York Ave., Newark 1, N. J.



# ECO

## NEWS

### INCORPORATION OF E. J. C. OPPOSED

Attempts of the Engineers Joint Council to incorporate in New York State as a nonprofit organization were defeated recently when the New York legislature failed to pass a bill introduced especially for this purpose. Under the present education law, the use of the word *engineer* or *engineering* in the name of nonprofit organizations is limited to those composed exclusively of licensed engineers.

Sudden opposition by the New York State Society of Professional Engineers to the bill, which was introduced by State Senator Williamson as an act to "incorporate Engineers Joint Council," is credited with the killing of the proposed law.

In a telegram to the state legislators the president of the New York State Society of Professional Engineers, Edward J. Nunan, said that E.J.C. was reorganized in January "to take over without sanction administration of engineering profession," and he termed the bill a "bold invasion of our learned profession by nonprofessional out-of-state groups seeking to dominate engineering profession in New York." Nunan further stated that "no legitimate reason exists for use of word *engineers* in title . . . any more than use of word *lawyer* or *doctor* in nonprofessional corporations."

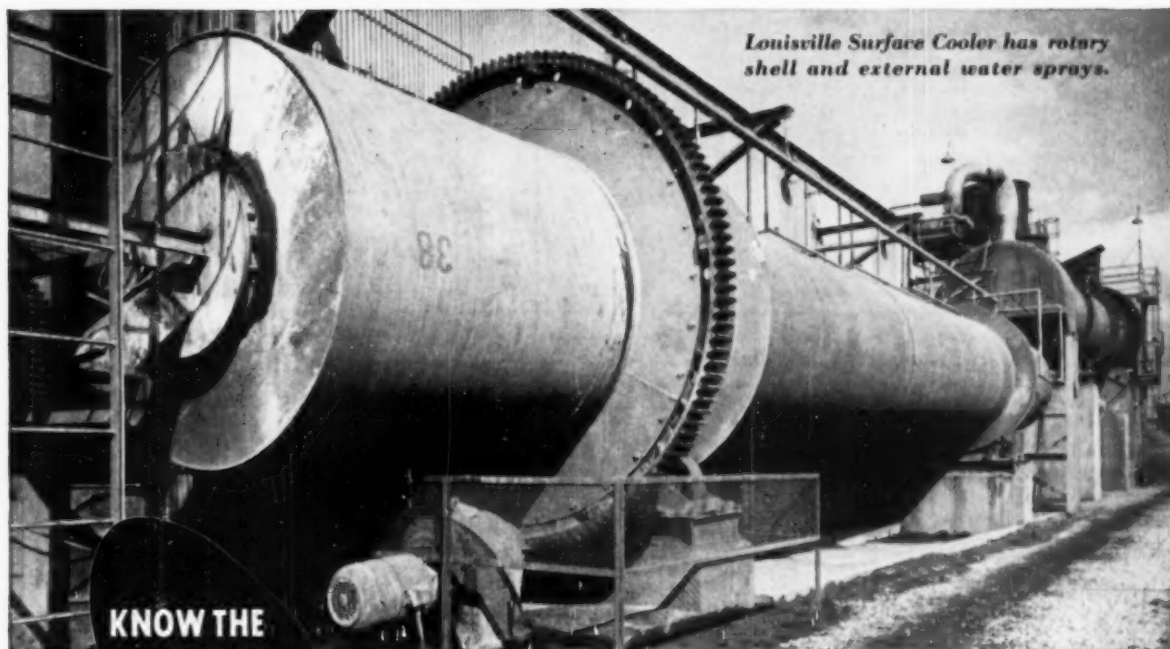
Engineers Joint Council is now composed of eight engineering societies: American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, American Water Works Association, American Institute of Electrical Engineers, Society of Naval Architects and Marine Engineers, American Society of Engineering Education, and American Institute of Chemical Engineers.

Officers of E.J.C., it was learned, feel that the New York education law restricts unduly the forming of organizations of engineers in the state. As the law now stands, an official pointed out, only engineers licensed in New York State can incorporate as a nonprofit membership organization in the state. Most of the E.J.C. societies are incorporated in New York, but had they not been incorporated before the passage of the law they could not now become so, he said, unless all their members everywhere were engineers licensed by New York State.

(More News on page 42)

See Louisville for  
**CREATIVE  
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ENGINEERING**

**Louisville Cooler does  
satisfactory job at low  
cost for nationally known  
chemical manufacturer...**



*Louisville Surface Cooler has rotary shell and external water sprays.*

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Turbo-Mixers, Evaporators,  
Dryers, Dewaterers, Towers,  
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... cooling lumpy calcined material from 1800° Fahr. to 150° Fahr. for further processing. Gentle mechanical handling required to minimize decrepitation.

Each Louisville cooler is "job-fitted" to your special problem—to make your cooling operations effective—to assure dependability of performance that will make the cooler operation pay.

Call in a Louisville engineer for a complete cooling survey. Based on his experience he will recommend one of the three standard Louisville types, a modification, or an entirely new design. *The performance will be pre-determined.* You'll know the results before you buy... and the results *must* be better! Write for complete information today.



### **Louisville Drying Machinery Unit**

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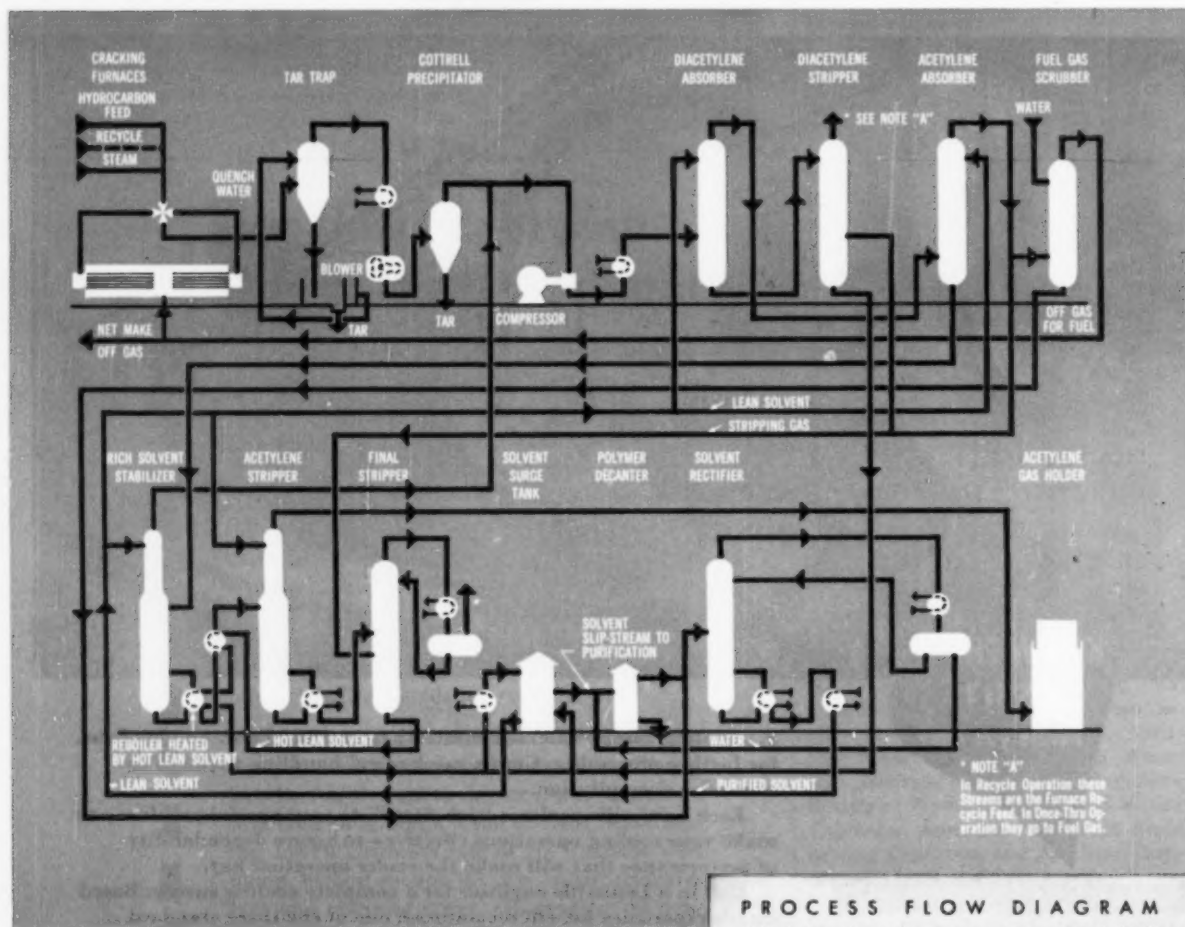
In Canada: Canadian Locomotive Company, Ltd.  
Kingston, Ontario

# NOW-ACETYLENE FROM HYDROCARBON FEED via the Wulff Process



With heavy demands for the hundreds of petrochemical end products that may be synthesized from acetylene, the need for low-cost acetylene as a raw material is becoming urgent. The Wulff Process now answers this need with a high purity acetylene at the lowest cost ever offered by any process. Any petroleum hydrocarbon conveniently vaporizable can be used as a feed stock.

Recent operations of the Wulff Process have proved it to be technically sound and commercially attractive. If your plant is convenient to a source of natural gas, ethane, propane, etc., it will pay you to investigate the possibilities of manufacturing acetylene economically by the Wulff Process.



The Wulff Process is available through Fluor, a name famous in process design, engineering and construction for the petroleum and chemical industries. For information on recent developments in this field, write for Bulletin EC-PA-0.002.

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### PROCESS FLOW DIAGRAM

This design flow scheme represents a typical Wulff Process plant for producing low-cost acetylene at 99+ volume percent purity from natural gas or propane. Two basic steps are involved: cracking of hydrocarbons to produce acetylene in a mixture of gases, and recovery and purification of the dilute product contained in the cracked mixture. Feed hydrocarbon is cracked in regenerative type furnaces heated by air-combustion of off-gas from the recovery section. No oxygen plant is required. The recovery and purification section is of conventional design operating at moderate temperatures and pressures. Only a single inexpensive readily-available solvent need be used. Operation is continuous and virtually automatic, requiring a minimum of operating personnel. Power demands are moderate, maintenance costs are low, hazards are negligible and there is practically no waste disposal problem.



# DATA SERVICE

## CHEMICALS

**1 • RUBBER-BASE PAINT.** Tropical Paint & Oil Co. announce Metakote rubber-base enamel to prevent corrosive action of chemicals, cleaners, moisture on metal surfaces. Tested for 27 hr. in 5% caustic soda at 140° F.

**2 • FATTY ALCOHOLS.** Announced by Stepan Chemical Co. line of higher fatty alcohols from tallow, other fats and oils. Called Mekanols, they are useful as emollients, emulsifiers, absorption bases, thickeners, etc. Sulfonates of Mekanols also available. For use in shampoos, household detergents, etc.

**3-4 • RESINS.** Goodyear Tire & Rubber Co. announces resins (3) Pliovic G90V and (4) Pliovic G80V. Manuals available contain physical properties, compounding, processing forming and formulations of these resins. Stability to deterioration by effects of heat and light.

**5 • n-BUTYL ACETATE.** Technical data sheet on n-butyl acetate from Commercial Solvents Corp. Lists specifications, physical properties, uses, toxicity, etc.

**6 • ORGANIC CHEMICALS.** Ten new chemicals added to list of more than 3500 from Eastman Organic Chemicals Department, Distillation Products Industries. Include acrylamide, formamide, malonic acid, phthaloyl chloride and others.

**7 • HIGH-SURFACED SODIUM.** Working manual and guide for use in development of specific formulations and for specific use of high-surface sodium, a form of metallic sodium from U. S. Industrial Chemicals Co. Tables, figures, applications, analysis, handling covered.

**8 • ALUM.** Aluminum sulfate—its history, manufacture, properties and

uses covered in 40-page booklet from American Cyanamid Co. Analyses, charts, etc.

**9 • INDUSTRIAL CHEMICALS.** Loose-leaf notebook from Tennessee Eastman Co., division of Eastman Kodak Co. covering aliphatic and aromatic chemicals. Also cellulose products and inorganic chemicals. Formula for each item, specifications, other pertinent data.

## BULLETINS

**10 • WEIGHING SYSTEMS.** Jeffrey Mfg. Co. line of Jeffrey-Traylor weighing, batching, and proportioning systems. Continuous gravimetric feeding, constant and variable speed operation, cutaway views, illustrations of equipment and uses, sizes, capacities, power and weights.

**11 • INDUSTRIAL PUMPS.** The Deming Co. industrial catalog of pumps for industrial service. Includes standard centrifugal, single, and ball bearing, suction, Motor Mount, portable, self-priming, rotary, etc. Well illustrated, tables and pertinent general information.

**12 • LIQUID LEVEL GAGES.** New data sheets from Jerguson Gage & Valve

Co. covering line of liquid level gage valves for tubular and flat gages. Illustrations show cross sections, rough dimensions. Complete specifications. Optional connections available.

**14 • PROPORTIONING PUMP.** Announced by Philadelphia Pump & Machinery Co. a new controlled capacity proportioning pump. Allows removal of parts without disconnecting pipe. Packing gland open at both ends simplifies replacement. Used on single, dual, or multiple combinations. Has manual, pneumatic, hydraulic, or electric control of stroke length.

**15 • STEAM ACCUMULATORS.** Foster Wheeler Corp. bulletin on steam accumulators to store steam automatically for peak demand. Comparative charts. Used in chemical processing, rubber, tobacco, oil refineries, etc. Provides constant pressure, reduced boiler capacity, etc.

**16 • COOLING TOWERS.** New by Binks Mfg. Co. mechanical draft cooling towers. Spray-deck construction, mechanical draft by blowers. Single, twin, and triple blowers. Capacity range 1 to 108 ton. Selection tables, general information.

Cards valid for only six months after date of issue

## Chemical Engineering Progress Data Service

*I would like to obtain more information on the items represented by the numbers I have circled.*

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**17 • PRODUCTS INDEX.** From B-I-F Industries, index of available bulletins on liquid feed systems, dry chemical feeders, recording, indicating and control instruments by %Proportioners%, Omega Machine, and Builders divisions.

**18 • REFRIGERATION.** Air conditioning and refrigeration units of Frick Co. Units from Freon-12, ¼ hp. to ammonia compressor, 1250 hp. Cutaway views, illustrations, tables, other details.

**19 • HEAVY DUTY AGITATORS.** Heavy duty agitators for open or closed tanks, from International Engineering, Inc. Specifications, dimensions, cutaway views, flat, curved, or pitched blade turbines. For hydrogenation, aeration, halogenation, flotation, gas-bleaching, deodorization, etc.

**20 • FERROLUM AND CUPRALUM.** Knapp Mills, Inc. bulletin on development of corrosion-resistant Ferrolum lead clad steel for use in storage and processing of sulfuric acid. Cupralum lead clad copper for coils used in heating or cooling acids and chemicals. Also Electro-Cupralum anodes.

**21 • PORTO-MULLER.** Portable mixer for chemical process industries from

Simpson Mix-Muller Division of National Engineering Co. Motor 3 hp., 1800 rev./min., interchangeable, adjustable mullers, capacity to 300 lb., cutaway view.

**22 • SERVICE MANUAL.** From Clarage Fan Co. loose-leaf service manual for maintenance use. Sections on arrangements, general information on various fans and heaters, literature, etc.

**23 • PRECIPITATOR.** Dollinger Corp. development for electronic air cleaning: Electro-Staynew precipitator to eliminate smoke, dust, and pollen from ventilation systems. Units of 100 to 400 w. Two sizes. Specifications, material list, cutaway views, other details in bulletin.

**24 • HEAT-EXCHANGER TUBE ENDS.** For use with any type of tube joint Flowrite heat-exchanger tube ends—metal inserts or wearing strips for inlet ends of condenser tubes. Plugging prevented, gas and air pockets eliminated. Graphs, comparative test reports, details in bulletin. Condenser Service & Engineering Co., Inc.

**25 • SANITARY FITTINGS.** Tri-Clover Machine Co. announces Tri-Clover stainless sanitary fittings. Offer great-

er speed and installation of take-down and permanent lines. Sizes 1½ to 4 in. Bulletin.

**26 • HYDRO-WYND.** Twin Disc Clutch Co. description of Hydro-Wynd tension control for use in winding textiles, papers, steel strip, Fiberglas, leather, rubber, plastic, etc. Automatic. Cutaway view illustrates operation.

**27 • CORROSION-PROOF EQUIPMENT.** Chemplas (a modified phenolic resin) for pipes, fittings, towers, pumps, etc. from General Ceramic and Steatite Corp. Bulletin tells when to use Chemplas, gives cutaway views, machining instructions, etc.

**28 • INDUSTRIAL METER.** Stainless industrial meter from Rockwell Mfg. Co. Corrosion-resistant for use in handling liquids in the cellulose, chemical, food, rubber, and pharmaceutical industries. Maximum capacity 100 gal./min. at pressures of 125 lb./sq.in. Bulletin.

**29 • SAFETY VALVE.** Automatic shut-off safety valve from Valco, Inc. Operates in any position, explosion-proof, for utilities, refineries, laboratories, chemical processes, etc. Bulletin on technical data, cutaway views.

**30 • PLUG VALVE CONTROLS.** Data sheet from Valve Controls on plug valve controls, either solenoid or manual. Assemblies for 2-in. plug valves, schematic operating diagrams, installation illustrated.

**31 • CORROSION-RESISTANT VALVES.** Duriron Co., Inc. type F valves in sizes ¼ through 1 in. Nonlubricated. Also available in 1¼, 1½, and 2-in. sizes.

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# DATA SERVICE

**32 • SCALES.** Ohaus Scale Corp. pamphlets on directions for use and maintenance of Harvard Trip balance and Triple Beam balance scales. Lists parts, gives numbered cutaway views.

**33 • PLATING PROCESS.** Kanigen, a new precision control, zero porosity, chemical plating process from Kanigen division, General American Transportation Corp. Technical data brochure covers application, thickness, hardness, physical characteristics, equipment and economics of chemical plating.

**34 • SELF-PRIMING PUMP.** Ralph B. Carter Co. Humdinger self-priming centrifugal pump. Hydraulically balanced volute design. Sizes 1½ in., 5500 gal./hr., to 10 in., 250,000 gal./hr. Various mountings, choice of drives.

**35 • INSTANT WATER HEATERS.** Johnston Corp. instant steam heaters for water or process liquids. Diagrams of installations, capacity tables at various temperatures and pressures, etc. in bulletin.

**36 • FLEXIBLE GEAR COUPLINGS.** Sier-Bath Gear and Pump Co., Inc. catalog of flexible gear couplings. Easily assembled and uncoupled without special tools. Data on engineering details, advantages, applications, etc.

**37 • DESIGN AND CONSTRUCTION.** Vulcan Copper & Supply Co. brochure on engineering and construction services for the organic chemical, petrochemical, pharmaceutical industries, etc. Low-temperature-gas separation, waste disposal, chemical recovery, etc.

**38 • LIQUID-LEVEL CONTROLLERS.** Pneumatic and electric liquid-level controllers from Moore Products Co. Ratings, modification, specifications, construction, cutaway views given in

bulletin. For the refining and chemical process industries.

**39 • PROCESS PUMPS.** For handling liquids, acids, caustics, De Laval Steam Turbine Co. process pumps. Leaflet describes interchangeability, design features, dimensions, capacity, and head range. Diagrams.

**40 • SOLENOID VALVES.** Direct-operated solenoid valves for automatic or remote flow control of liquids, steam to 400° F., and high viscosity liquids described in bulletin from Johnson Corp. Capacity tables, diagrams, cutaway views of various types.

**41 • RUBBER PARTS AND EQUIPMENT.** Services of Automotive Rubber Co., Inc., covered in current illustrated bulletin. Small, bare and rubber-covered stampings, manufacture of synthetic and natural rubber, rubber-lined tanks and pressure vessels, and other parts.

**42 • AUTOMATIC VALVE SPECIALTIES.** Comprehensive loose-leaf catalog from Davis Regulator Co. covers complete line of pressure, flow, and liquid level controls for steam, air, gas, water, oil, and other fluids. Details on each item, cutaway views, dimensions, etc.

**43 • STOCK CUTTING MACHINERY.** From Taylor, Stiles & Co. notebook on cutting machinery for the paper, rubber, chemical industries. Sheet covering each type gives diagram, specifications, construction, illustrations.

**44 • HELICAL SPEED REDUCERS.** Designed for continuous coupled operation to electric motors, W. A. Jones Foundry and Machine Co. worm-helical speed reducers. Integral helical pinions. Bulletin contains cutaway views of assembly types, horsepower ratings, ratios, torque charts, etc.

**50 • FLUID ENERGY MILL.** Ultragrinding process to make particles in low

and submicron sizes. C. H. Wheeler Mfg. Co. fluid energy mill handles abrasives, pigments, chemicals, foods, etc. Moving particles, no moving parts. Folder.

**51 • TEMPERATURE CONTROL.** For process and design engineers, plant managers, revised edition of Partlow Corp. manual on temperature measurement and control. Discusses nine types of temperature response and use.

**52 • PLATE MAGNETS.** Eriez Mfg. Co. bulletin on permanent, nonelectric plate magnets for removal of tramp iron. Traps tramps iron in flows 2 in. deep. Designed for wood spouts, chutes, hoppers, feed tables. Units 4 to 24 in. wide.

**53 • PLUNGER RELAY.** Hermetically sealed, flickerproof Mercury plunger relay described in Ebert Electronics Co. folder. Operates on ½ wave unfiltered current; loads to 35 amp., 115 v.; 25 amp., 230 v. ac. Contact in 35 milliseconds, 55 milliseconds, to break.

**54 • INSULATED PIPE.** Durant Insulated Pipe Co. report on simulated operating tests. Details on methods, temperature recordings, results on pipe buried 48 in. with effects of water and high temperature on casing.

**55 • ELECTRIC DEHUMIDIFIER.** A self-contained air-drying unit from Air Conditioning Division of Remington Corp., to remove excess humidity from plants, storage rooms, laboratories. Operates at room temperatures 60 to 110° F., relative humidities of 40 to 100%. Compressors 1 and also 1½ hp. Descriptive folder.

**56 • CENTRIFUGAL PUMPS.** Three new centrifugal pumps added to line of Pioneer Pump, Division of Detroit Harvester Co. Separate intake bracket and discharge piping, handles high solids and abrasive suspensions. Easily cleaned. All sizes of each model available.



**57 • TURBINE PUMPS.** From U. S. Electrical Motors, Inc. colored bulletin, illustrated, cutaway view of its Holloshaft right-angle gear drive for turbine pump. For use in location without electricity, for the process and other industries. Weatherproof from any angle, leakproof shaft seal, reverse protection clutch featured.

## EQUIPMENT

**60 • TUBE END REDUCER.** Added to Parker Appliance line Ferulok tube end reducer. Converts any Ferulok fitting into combination size unit. Available for all reductions within size range of 1/4 to 1 in. O.D. tubing.

**61 • CARBON STEEL CHART.** Peter A. Frasse & Co., Inc. offer revised carbon steel chart. Gives government specification analyses, shows nearest corresponding SAE, AISI, and AMS numbers.

**62 • HIGH SPEED MIXER.** For rapid blending of liquids and powders the Norman mixer from Cherry-Burrell Corp. Blends mixture 50% liquid and powder. For mixing yeast, milk powder, chemicals; made of stainless steel. Capacities 8, 15, 25, 50 and 75 gal. Stationary and mobile units.

**63 • FLOW METERS.** Set of specification sheets on flow meters of Brown Instruments Division, Minneapolis-Honeywell Regulator Co.

**64 • INFRARED ANALYZERS.** Two new infrared analyzers added to line of Perkin-Elmer Corp. Bichromator, a two-color or wavelength analyzer; Tri-Non selective triple beam, non-dispersion analyzer. Both thermostated to operate 0 to 120° F. Meet safety requirements.

**65 • PRUF COAT SEALER.** Prufcoat Laboratories, Inc. sealer for asphalt, coal tar or similar coatings, to give chemical resistance of vinyl without bleeding or staining. Consists of selected synthetic resins and combinations of leafing-type metallic pigments.

**66 • CENTRIFUGAL PUMP.** Goulds Pumps, Inc. close-coupled centrifugal pump for air conditioning requirements and other industrial applications. Heads 110 ft.; electric drive motors 1/4 to 2 hp. Discharge outlets tapped for 1- or 1 1/4-in. pipe.

**67 • MOTOR VALVES.** Air-operated diaphragm motor valves from Brown

Instruments Division, Minneapolis-Honeywell Regulator Co.

**68 • NEOPRENE COATINGS.** Pennsylvania Salt Mfg. Co. system of anti-corrosion coating. NeoCoat and NeoPrime A for most surfaces, NeoPrime B for concrete. Coatings are plastic, polymerization taking place after application.

**69 • LABORATORY SUPPLIES & REAGENTS.** From Arthur S. LaPine & Co. 900-page catalog B containing listing of their complete line of laboratory equipment and apparatus for assay, chemical clinical, materials-testing and metallurgical laboratories.

**70 • MINDICATORS.** Series of vertical scale indicating instruments known as Mindicators from Dickson Co. Units have 4-in. scale requiring transmitted pressure 3 to 15 lb./sq.in.g. Range from -200° F. to 1000° F. Capillary connecting tubes to 150 ft.

**71 • PLASTIC TAPE.** Labelon, a plastic labeling tape from Labelon Tape Co., Inc. Adheres without moistening to any smooth, dry, clean surface. Takes written impressions by use of stylus. Protects against smudging by oil, grease, chemicals. Not affected between -40° to +150° F. Colors in variety of lengths and widths.

**72 • COLORIMETER.** Bausch & Lomb Optical Co. improved monochromatic colorimeter. Used in analytical work, biochemistry, food processing, metallurgy, etc.

**73 • HUMIDITY INDICATOR CARDS.** Davison Chemical Corp. humidity indicator cards with Tel-Tale spots. Used in dehydrated packaging. Cards have three or six spots, are furnished with eyelets for attachment. Three-spot card changes at 65, 40, and 30%; six-spot graduated 10 to 60%. Accuracy  $\pm 5\%$ .

**74 • FLOW CONTROL VALVE.** Designed to control speed of piston stroke in cylinder. Sizes from 1/4 to 1 1/4 in. Airmatic Valve, Inc. Control is by stem and special floating bevel seat poppet.

**75 • TUBING.** Electric weld tubing from Nikoh Tube Co. Bulletin gives applications, types available, tables on conversion, gages, tolerance, sizes.

**76 • METAL MESH.** Precision metal mesh, custom made by Denholme,

Inc. in wide variety of designs and alloys. Gages 0.008 to 0.080 in. For filters, strainers, grilles, etc. Samples available.

**77 • GRAPHITE COMBUSTION CHAMBERS.** Catalog section from National Carbon Co. on graphite combustion chambers with Karbate impervious graphite burner nozzles. Unit designed for burning gases from cells; burning *sniff gas*; re-evaporated, dried, or cooled chlorine. Dimensions, sizes, capacities, etc. Emphasizes corrosion resistance to hot cell gases saturated with water.

**78 • PACKAGED PLANT CONSTRUCTION.** Description of service from planning to construction of chemical and industrial plants. Brochure from Wigton-Abbott Corp.

**79 • CYCLOFLEX COATING.** Liquid coating converted to flexible rubber-like film by heating. Can be applied to metal parts. Abrasion resistant. Thickness from 1/32 to 1/2 in. Meets temperature and fungus resistance requirements. Munray Products, Inc.

**80 • AIR CONDITIONER.** Niagara Blower Co. air conditioner controls humidity using Hygrol liquid absorbent. Adds 17,000 cu.ft. dry air/min. to 56,000 cu.ft. of air in circulation. Fans provide for removal of 15,000 cu.ft. of stale air. Smoke and odors eliminated by slight positive atmospheric pressure.

**81 • STEAM TRAPS.** Bulletin on W. H. Nicholson & Co. industrial steam trap. New design, smaller size and capacity. Bronze, sizes 1/4, 3/8, 1/2 and 3/4 in. Angle type from vacuum to 200-lb. pressure.

**82 • LIQUID FILTERS.** Dollinger Corp.'s bulletin on Staynew liquid filters. Describes radial fin construction permitting large filter area. Wide range of liquids filtered. Covers capacities, pressure ranges, efficiency, low maintenance along with suggested filtering media. Data sheet.

**83 • SERVICE-PARTS CATALOG.** Claud S. Gordon Co. catalog covers service on industrial furnaces, control instruments, gages, thermometers, thermocouples, etc. Specification tables on all items.

**84 • FLOW METERS.** Both pneumatic and electric flow meters by Republic Flow Meters Co. listed in bulletin. For measuring fluctuating flows, corrosive, viscous or vaporous liquids.





**PERFORMANCE CLAIMS** call for proof—especially when the subject is anodes. You can make anodes with every one of the features you know they should have—controlled density, uniform structure, high purity and mechanical strength, low electrical resistance. And you can be pretty sure they'll give top performance. But to be really sure you have to get *on-the-job proof*. At ICE that's just what we do. Before we put any new-type anode into production, we first put it into actual operation in the process for which it has been designed. We test it, we study it, we learn everything there is to know about its behavior. That way, when we make our performance claims, we're not just guessing. We know ICE anodes produce purer products. We know they last longer. And we know we can say to you, with perfect confidence: Specify ICE!

## INTERNATIONAL GRAPHITE & ELECTRODE DIVISION

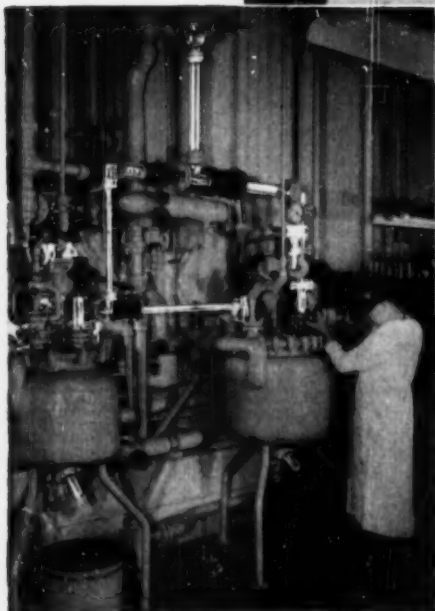
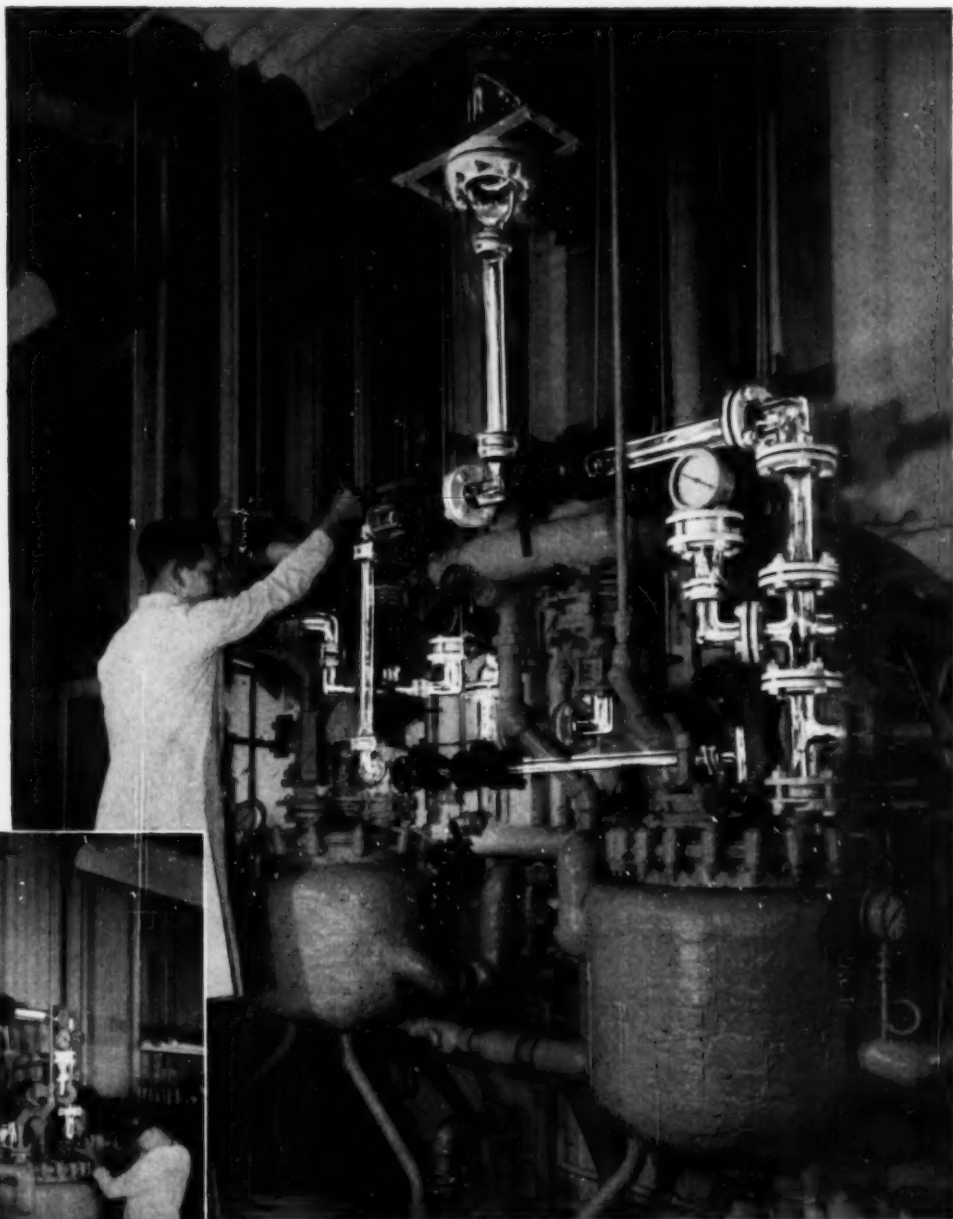
**SPEER CARBON COMPANY**

St. Marys, Pennsylvania

Other Divisions: Jeffers Electronics • Speer Resistor

# How CALCO uses PYREX<sup>®</sup> pipe in

Jacketed kettles cross-connected through PYREX<sup>®</sup> brand



The Jacketed kettles shown in the two views of this Calco test-run installation supply experimental products to a glass heat exchanger through 1" and 2" PYREX brand "Double-Tough" glass pipe and fittings, and a 3" glass vapor trap. Teflon gaskets are standard. Temperatures range from 125°C. to -10°C.

Pressures from 14 PSI to a vacuum of 29" of mercury. The pH range is from "very low" to 10. In the left-hand picture the operator is charging one of the kettles with concentrated acid. In the right-hand picture, he is making a valve adjustment.

# processing pharmaceuticals

glass pipe permit either distilling or refluxing

The purity of pharmaceuticals manufactured by Calco Chemical Division, American Cyanamid Company, in its Bound Brook, N. J. plant requires the use of much glass processing equipment.

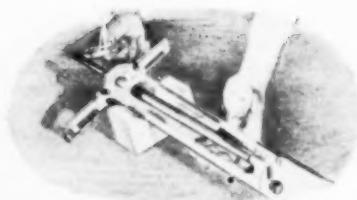
The two-still installation illustrated here is used to test run new pharmaceuticals and intermediates on a production scale a step above laboratory operations. Materials handled cover the entire pharmaceutical field, and involve a wide variety of corrosives.

According to Dr. J. M. Smith, Assistant Manager of Pharmaceutical Research, this installation's flexibility of operations is considered unlimited so far as pharma-

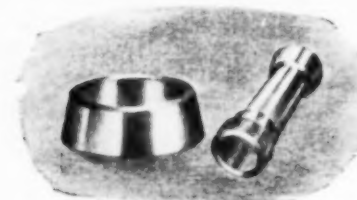
ceuticals are concerned. Part of its flexibility is due to the manner of cross-connecting the kettles so that it is possible to distill or reflux from either kettle. Most frequently, the kettles are used independently, or alternately, according to need. Both feed into one condenser.

This is only a small example of Calco's use of PYREX brand "Double-Tough" glass pipe in the production of pharmaceuticals and intermediates. Its other six plants use PYREX pipe wherever corrosion or product purity are problems. You will find it well worth your time to check the many advantages PYREX pipe offers.

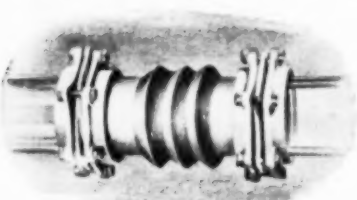
## Installation Tips



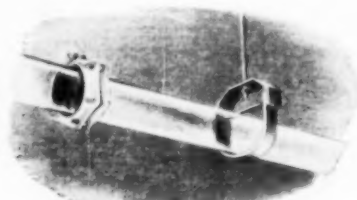
PYREX pipe can be prefabricated to your exact measurements or cut and beaded on the job by your own men with the aid of a simple tool kit.



Corning adapter flanges or ferrules are available for connecting PYREX pipe to other pipe materials, valves, or tank nozzles. Complete fittings also available.



Where excessive vibration is encountered, a Teflon bellows may be used in the line. Adjustable glass joints and spacers permit wide flexibility of layout.



Pipe hangers can be the same as used for metal pipe. It is recommended that a resilient material be used as padding to prevent scratching of glass.

The PYREX pipe distributors listed below carry the complete line

Contact the one nearest you:

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Please send me the printed information checked below:

- ☐ "PYREX brand "Double-Tough" Glass Pipe and Fittings" (EA-3)  
☐ "PYREX brand Glass Pipe in the Process Industries" (EA-1)  
☐ "PYREX Cascade Coolers" (PE-B)

Name \_\_\_\_\_

Title \_\_\_\_\_

Company \_\_\_\_\_

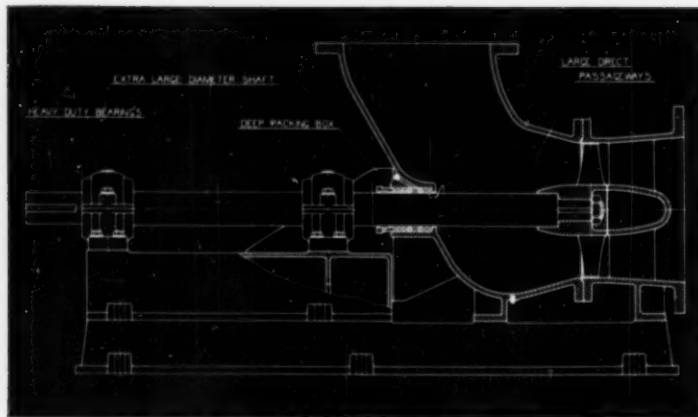
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Lawrence 24" Horizontal Circulating Pump of Nickel Alloy Construction



Cross Section of Lawrence Horizontal Propeller Pump

## PROPELLER PUMPS FOR THE CHEMICAL and PROCESS INDUSTRIES

Lawrence Propeller or Axial Flow Pumps are widely used to circulate large volumes of liquid or slurry against low heads as in evaporators, crystallizers, etc. This type of pump is particularly well adapted for circulating service because of its simplicity, high efficiency, and low first cost. The flow can be arranged in either direction and the casing turned to any position desired to serve as an elbow. The capacity can be closely regulated by varying the speed—very important in crystallization processes where a uniform velocity must be maintained.

Lawrence Propeller Pumps are made of the metals and alloys best suited for their ability to resist the corrosive and abrasive action of the liquid pumped.



Write for Bulletin 203-6 for summary of acid and chemical pump data.



# LAWRENCE PUMPS INC.

371 MARKET STREET, LAWRENCE, MASS.

## RECORD ENROLLMENT

(Continued from page 24)

service until graduation is more socially palatable in the case of scientific and technical training than in other areas of study."

### Graduate Students

Contrary to the undergraduate record, there has been a continued increase in graduate enrollment since the war, the present figure of 20,348 representing a 7.8% rise over 1951 and nearly 300% more than were enrolled in 1940. The steady increase in graduate enrollment is, according to the survey, "a reflection of the demand of industry for persons with training beyond the baccalaureate degree. . . . Undoubtedly, most of these students are employed engineers who have recognized the necessity for advanced training either to improve their position or to better their understanding of the more complex engineering processes which are developing today." The percentage of all engineering students enrolled in graduate courses (12.8) is, however, slightly lower than in 1951 (13.1), owing to the substantial undergraduate increase. The total college enrollment includes 10% in graduate schools.

### Degrees

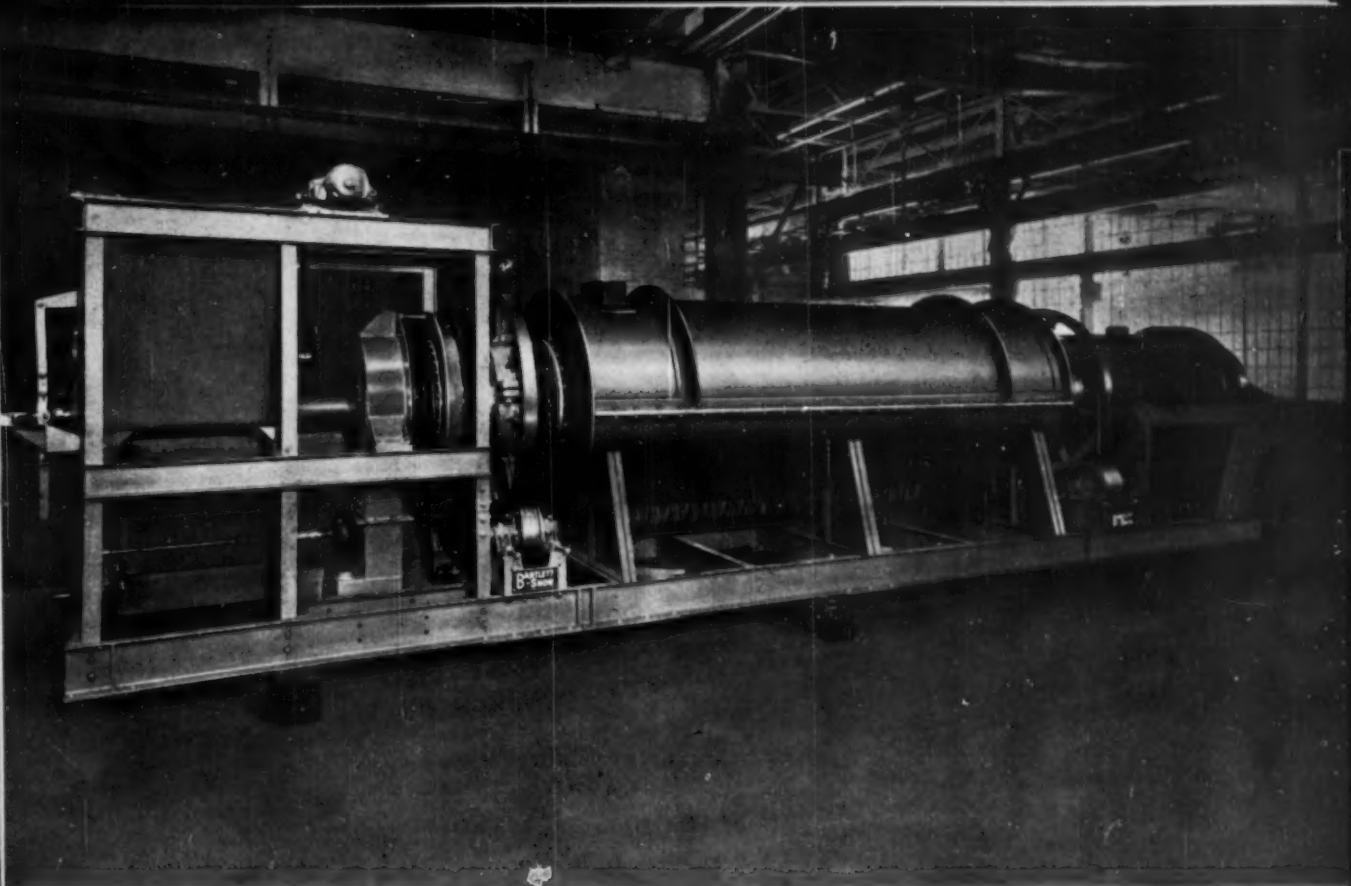
Of the 27,155 first degrees in engineering granted in 1952, 2,743 were in chemical engineering. Mechanical engineering curricula gave 6,823 degrees; electrical, 5,876; and civil, 4,917. Nine chemical engineering degrees went to women. In mechanical engineering eight women received degrees, and electrical and civil granted six each. Advanced degrees in chemical engineering for this period numbered 540 for the master's and 159 for the doctorate; for the other leading engineering fields there were 990 master's degrees and 121 doctorates in electrical, 627 master's and 68 doctorates in mechanical, and 571 master's and 43 doctorates in civil engineering. More than 40% of the doctorates in these four fields went to chemical engineers.

## SYMPOSIUM AT ANN ARBOR

A symposium on Flow Through Porous Media is being planned by the division of industrial and engineering chemistry of the American Chemical Society for Dec. 28 to 29, 1953, at the University of Michigan. Emphasis will be placed on the flow of single- or multiple-phase fluid through small passages with solid boundaries. Chairman of the program is Professor J. L. York, department of chemical engineering, University of Michigan.

(More News on page 44)

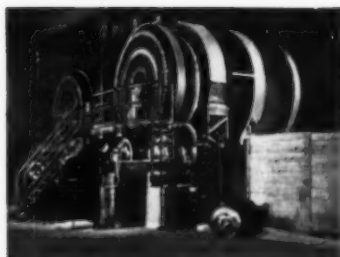




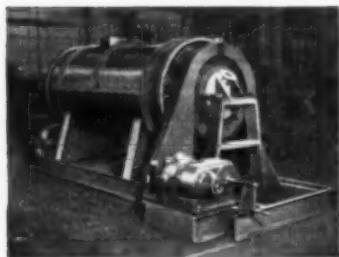
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● These units permit materials to be processed continuously at temperatures from 900° F to 2100° F in a reducing, oxidizing or neutral atmosphere, cooled, and discharged at 200° F or lower. The chrome nickel alloy tube can be lined if desired, to permit processing without bringing the material into contact with metal at elevated temperatures. Feed hopper, variable feeder, seals and breechings are all supported on a single frame to assure proper alignment and efficient trouble-free operation. Our complete laboratory and experimental facilities enable us to determine accurately the time cycle, temperature, pitch, rate of feed, special atmosphere and all other conditions needed to produce a given result, before the production unit is designed or built. Let us work with you on your next job.

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• The huge expansion of the chemical industries gave Haveg an order backlog that resulted in long deliveries and forced some of our customers to seek substitutes or to use less satisfactory materials.

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### GIANT TEST TUBE



Above is a new 70,000-gal. test tank erected by Mixing Equipment Co. at Rochester, N. Y. The company expects to use the new research installation to obtain data on blending of fluids in big tanks and to make quantitative studies on blending operations. Data are to be taken on single and multiple installations of side-entering mixers, location of multiple units, angle of entrance of mixers, and comparisons between mechanical mixers, air agitation, and liquid jets.

### M.I.T. SUMMER COURSES

Two integrated programs, one in infrared spectroscopy and one in instrumental chemical analysis, and a special program on thermodynamics of equilibrium and nonequilibrium states, will be offered at the Massachusetts Institute of Technology this summer. There will also be a two-week course on the analysis and synthesis of feedback control systems.

The course in technique of infrared spectroscopy will be held from July 6 to 10. The course in applications, offered from July 13 to 17, will cover theory, interpretation, and use in chemical analysis.

The course in electrical methods of instrumental chemical analysis will be held from August 17 to 21 and optical methods will be considered from August 24 to 28.

The thermodynamics program, presented from June 29 to July 10, will include lectures, etc., and small discussion groups, and laboratory visits.

The course on feedback control systems will be given from June 22 to July 3. The first week will be devoted to a review of the theory of measurement and feedback control. The second will deal with advanced subjects.

Further information may be obtained from the Director of the Summer Session, Room 3-107, M.I.T., Cambridge 39, Mass.

(More News on page 54)

for either of these  
**CHEMICAL PUMPING**  
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**MEDIUM to  
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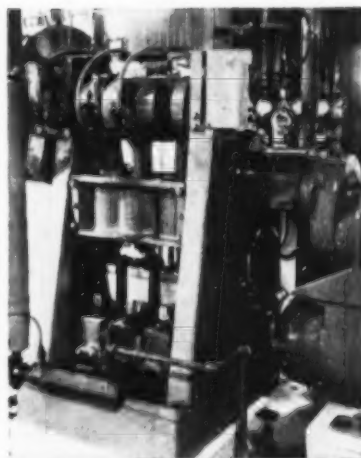
**FOR AUTOMATICALLY CONTROLLED DELIVERY** use an Aldrich-Groff "POWR-SAVR." This variable stroke triplex pump controls delivery from 0 to 100% of capacity at constant pump and motor speed . . . can be controlled from any remote point, manually or automatically. Power requirements are low, because consumption is directly proportional to demand.

"POWR-SAVR" pumps handle any free-flowing liquid at discharge pressures from 300 to 15,000 psi and are available in six sizes—from 2" to 6" stroke and from 5 to 125 bhp. For more information on these versatile pumps, write for Data Sheet 65.

**FOR MEDIUM TO HIGH PRESSURE SERVICE** several types of constant stroke pumps are available—depending upon the service involved. You may need the Inverted Vertical Triplex (Data Sheet 66), the Vertical Triplex (Data Sheet 26), or the Direct Flow Triplex or Multiplex Pump (Data Sheets 64, 64B). (All these helpful data sheets are available upon request.)

From our experience in building pumps for the chemical industry, we can—from our engineering and service files—frequently make specific recommendations to meet your chemical pumping needs. Whatever your problem, we welcome your inquiries.

Aldrich Pumps are ideal for applications involving corrosion, abrasive materials, high viscosity or high pressure. Among many liquids handled by Aldrich Pumps are: caustic solutions, fatty acids, nitric acid, acetic acid, aqua ammonia, anhydrous ammonia, as well as liquids encountered in the petroleum refining, petroleum chemical, and other industries.



This Aldrich Vertical Triplex Pump—on the job at the Burlington, N. J., plant of Hercules Powder Company—is employed to pump rosin ester in the manufacture of Abitol, hydroabietyl alcohol, used in lubricants and in the manufacture of alkyd resins. In this application pump capacity is one gallon per minute against 6,000 pounds discharge pressure.

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 Direct Flow Pump*

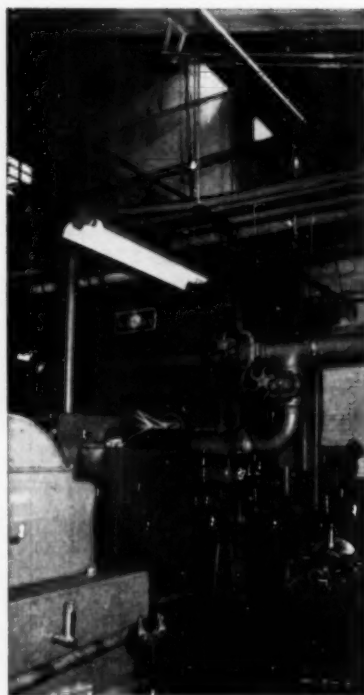
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You are assured of uniform, constant production and quality from any process . . . steady, reliable operation . . . lower cost for more dependable cooling. You can have closed system cooling with freedom from scale, dirt, corrosion and maintenance troubles. You can accurately cool more than one type of liquid with one machine.

The Niagara Aero Heat Exchanger uses atmospheric air to cool liquids and gases by evaporative cooling. You can remove heat at the rate of input to keep accurate control of gas or liquid temperature. You can put heat back into the system to save the losses of a "warm-up" period or to equalize the effect of load variations.



Great savings in cooling water and savings in piping, pumping and power return the cost to you quickly. The Niagara Aero Heat Exchanger can save you approximately 95% of your cooling water cost. Send for Bulletin 120.

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## **MARGINAL NOTES**

### *Something Old and Something New*

Proceedings of the General Discussion on Heat Transfer. Institution of Mechanical Engineers, London, available in the U. S. from the American Society of Mechanical Engineers, 29 West 39 Street, New York, N. Y. xiii + 496 pp. \$10.00 postpaid.

*Reviewed by James N. Addoms, Massachusetts Institute of Technology, Cambridge, Mass.*

The General Discussion on Heat Transfer which was held in London on Sept. 11-13, 1951, under the joint sponsorship of the Institution of Mechanical Engineers and the American Society of Mechanical Engineers, with the co-operation of more than fifty participating societies, represented an outstanding achievement in the compilation of more than ninety papers dealing with current investigations in all fields of heat transfer. While a few of the papers were previously available, at least in report form, most of the material will be new to American readers. A limited number of paper-bound reprints of the five technical sessions were previously available, but these did not contain the numerous discussions of the papers and the authors' replies. The present volume brings all of this material together.

The object of the General Discussion was to review "developments in the knowledge of the principles of the transference of heat, and in the design of apparatus making use of such knowledge, which has taken place during the period 1940-50." For this purpose the subject matter was divided into five headings: Heat Transfer with Change of State; Heat Transfer between Fluids and Surfaces; Conduction in Solids and Fluids; Radiation, Instrumentation, Measurement Techniques and Analogies; and Special Problems.

It is interesting to note that the average North American paper is more than twice as long as the average overseas contribution. The former are generally more complete and perhaps of more immediate interest to the designer; the latter appeal to the research worker.

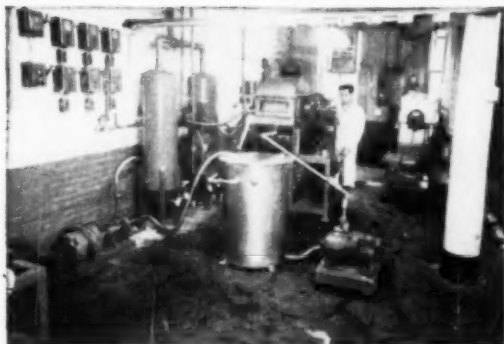
The book also contains the Clayton Lecture, "Problems in Design and Research on Condensers of Vapours and Vapour Mixtures," by A. P. Colburn; a summary of the closing technical session; an author and a subject index.

The careful screening of papers by the various committees has resulted in a valuable group of technical contributions essential to specialists in the field.

(More Marginal Notes on page 48)



# HOW TO GET THE **MOST** FOR YOUR MONEY IN VACUUM FILTRATION



LABORATORY FILTER SERVICE



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EXPERIENCED FILTER CONSTRUCTION

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There are 5 basic requirements that should be considered.

1. The product to be filtered should have the benefit of competent Laboratory or Pilot Plant test work;
2. Careful study of the determinations made in the test work and a selection from these facts of the proper filter as to type and size;
3. Picking a manufacturer with the experience and Engineering ability for proper design;
4. Securing your filter from a manufacturer whose facilities for production are adequate to meet all requirements;
5. Picking a manufacturer with a trained and experienced service organization to make sure that the final installation meets the results which the test work indicated.

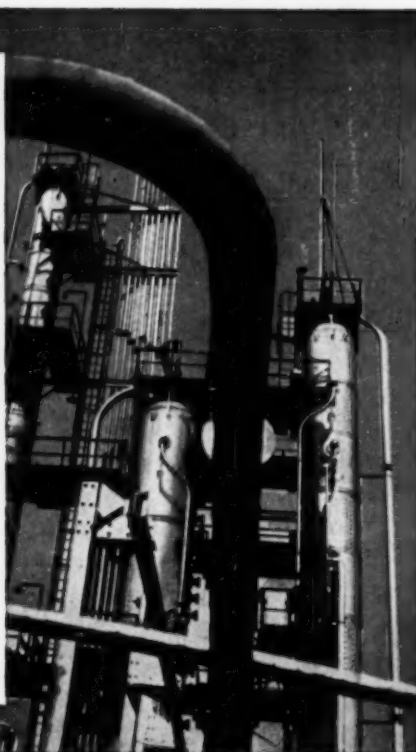
The selection of an EIMCO Filter will enable you to meet all of these basic conditions four-square:

1. Our Testing Laboratory is one of the best in the industry, not only from the standpoint of facilities, but capable personnel as well;
2. Our Sales Engineers with the benefit of thousands of installations in every type of metallurgical and processing industry are able to make an informed selection based on laboratory determinations as to the proper type and size;
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662 East First Avenue, Roselle, N. J. Canadian Plant, Hamilton, Ont.



## MARGINAL NOTES

(Continued from page 46)

### One for the Book—Shelf

**Vinyl and Related Polymers.** Calvin E. Schildknecht; John Wiley & Sons, Inc., New York (1952). 723 pp. \$12.50.

*Reviewed by Turner Alfrey, Jr., Physical Research Laboratory, Dow Chemical Co., Midland, Mich.*

This book provides a comprehensive summary of addition polymers—their preparations, properties, and applications. During the past two decades, industrial production of synthetic polymers has expanded at a fantastic rate, and the rapid growth is still continuing. Plastics, synthetic fibers, and synthetic rubber have accounted for most of this growth, but many other uses have also developed, ranging from surface coatings to blood substitutes. Along with this industrial development there has been a bewildering multiplication of the literature on vinyl polymers.

In the case of a few polymers, such as polystyrene, critical summaries of the literature in book form have previously been available. In his new book, Schildknecht covers not only these standard materials, but also such newer polymers as polyethylene, polyvinyl ethers, polyisobutylene, polyacrylonitrile, fluorovinyl polymers, and many others. Butadiene copolymers are also discussed.

The book is organized on the basis of different types of vinyl polymer. In each case, the treatment includes monomer preparation, polymerization, and the properties and end uses of the polymer. The style is factual rather than mathematical and speculative.

One attractive feature of the book, which should make it particularly useful to industrial chemists and engineers, is the coverage of the patent literature.

"Vinyl and Related Polymers" is a book which belongs on the shelf of every chemist and engineer, who is at all concerned with technical problems involving addition polymers. It is a book which will not merely be read, but will be continually consulted.

### Books Received

**Elasticity in Engineering.** Ernest E. Sechler. John Wiley & Sons, Inc., New York (1952). ix + 419 pp., \$8.50.

**Rocks for Chemists.** S. J. Shand. Pitman Publishing Corp., New York (1952). xii + 146 pp. and 32 plates, \$4.50.

**Organic Syntheses.** Vol. 32. R. T. Arnold, Editor-in-Chief, John Wiley & Sons, Inc., New York (1952). vi + 119 pp., \$3.50.

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any mill condition and any stock condition can  
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1. The one best, exact, commercially practical method of drying your product.
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3. Air flow data
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5. Required heating surface
6. Dryer length and design
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9. Possible simple changes in stock preparation prior to drying, to attain maximum quality and efficiency.
10. Controls required to maintain quality and quantity drying in uniform, continuous production.



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INDUSTRIAL SPRAY NOZZLES  
AND COOLING TOWERS

## CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 7, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Active Members will receive careful consideration if received before June 15, 1953, at the Office of the Secretary, A.I.Ch.E., 120 East 41st, New York 17.

### Applicants for Active Membership

Bardin, J. S., Pittsburgh, Pa.  
Belcher, Donald W., North Branch, N. J.  
Biosca, Frank E., Martinez, Calif.  
Bless, Frank W., Jr., Piney River, Va.  
Bogie, Harlan G., Homewood, Ill.  
Bueker, Richard W., Wakefield, Mass.  
Carlson, Einar T., New York, N. Y.  
Carnell, William C., Orelana, Pa.  
Colucci, F. W., E. Orange, N. J.  
Cooley, Alfred B., Wauwatosa, Wisc.  
Cunningham, F. Graham, New York, N. Y.  
Delavan, David, Pasadena, Tex.  
Duffy, Ben King, Pittsburgh, Pa.  
Edge, Dexter, Jr., Tacoma, Wash.  
Ellis, Earl T., Petersburg, Va.  
Erwin, Harry L., Kingsport, Tenn.  
Gibble, George W., Fort Lee, N. J.  
Gould, G. D., Richmond, Calif.  
Hines, Bedford, Jr., Kirkwood, Mo.  
Hock, Walter, Jr., Glenview, Ill.  
Huxster, Fred G., Wilmington, Del.  
Jones, Sam O., Winston Salem, N. C.  
Koiser, Marvin M., New York, N. Y.  
Keenan, W. F., III, Charleston, W. Va.  
Leary, Russell S., Jr., Philadelphia, Pa.  
Lehman, Paul E., Penns Grove, Pa.  
Ma, Chuk Ching, Woodside, N. Y.  
Martin, Ralph E., Somerville, N. J.  
McCauley, Samuel K., Upper Darby, Pa.  
McCutchan, Roy T., San Antonio, Tex.  
Milford, R. P., Oak Ridge, Tenn.  
Muffat, Donald L., Whiting, Ind.  
Pryor, Bodie C., Port Arthur, Tex.  
Pyle, John W., Knoxville, Tenn.  
Ricards, Harold A., Westfield, N. J.  
Rice, John C., Hackensack, N. J.  
Scott, Louis D., Martinsville, Va.  
Smith, Reginald C., New York, N. Y.

Taylor, Francis M., New Orleans, La.  
Weintraub, Murray, Pittsburgh, Pa.  
Wilke, C. R., Berkeley, Calif.

### Applicants for Associate Membership

Adams, James O., Freeport, Tex.  
Borg, Arthur C., Whiting, Ind.  
Britt, Martin L., Jr., Blackville, S. C.  
Camey, Paul Van A., Brooklyn, N. Y.  
Lee, K. T., New York, N. Y.  
Muller, J. A., Houston, Tex.  
Von Fischer, W., Cleveland, Ohio

### Applicants for Junior Membership

Aldredge, Glenn E., Tulsa, Okla.  
Askey, Warren E., Baytown, Tex.  
Badger, John William, Parlin, N. J.  
Bass, Irvin L., Akron, Ohio  
Bey, Lois A., Chicago, Ill.  
Black, K. M., Paterson, N. J.  
Bolen, William R., Texas City, Tex.  
Brusenback, Robert A., Claymont, Del.  
Bryant, Walter M., Army Chemical Center, Md.  
Burk, Richard O., Washington, D. C.  
Calkins, Frank M., St. Louis, Mo.  
Cathcart, William R., Waynesboro, Va.  
Chalpin, William, Flushing, N. Y.  
Coleman, William G., Richland, Wash.  
Coma, James G., San Jose, Calif.  
Connaughton, James M., E. St. Louis, Ill.  
Crawford, Richard W., Akron, Ohio  
Dieckmann, Karl W., Claymont, Del.  
Edmiston, David C., Jr., Beaumont, Tex.  
Finney, Carl F., Chattanooga, Tenn.

(Continued on page 52)





## "Wonder-worker" for the wonder drugs

**How  
Celite  
filtration  
assures purity,  
speeds production**

When producers of antibiotics sought a filter aid that would assure removal of all mycelium and other gelatinous impurities in the broth from which wonder drugs are extracted—and speed their "put-through" in the bargain—Celite ended the search.

The effectiveness of Celite can be attributed to these important factors which make it unique among filter aids:

Carefully processed from the purest deposit of diatomaceous silica known, Celite is available in nine standard grades—each designed to trap out suspended impurities of a given size and type. Whenever you reorder, you are assured of the same uniform, accurately graded powder re-

ceived in your initial order. Thus, with Celite, you can count on consistent purity in your filtrates—at highest rate of flow—month after month, year after year.

The manufacture of wonder drugs is just one of the many processes in which consistent purity and faster filtration have been obtained through the use of Celite. Your own filtration problem, regardless of the product involved, can no doubt be solved with the proper grade of Johns-Manville filter aid. To have a Celite Filtration Engineer study your problem and offer recommendations, without cost or obligation, just write Johns-Manville, Box 60, New York 16, N. Y.

Celite is a registered Johns-Manville trade mark



**Johns-Manville CELITE**  
**FILTER AIDS**

# SECRETARY'S REPORT

NEWS

(Continued from page 44)

S. L. TYLER

Again, for the month of April, the matters to be considered by the Executive Committee were of a general routine nature and votes were taken by mail. The Executive Committee approved the Minutes of the previous Executive Committee meeting, and the Treasurer's report for February.

As no negative votes were received up to April 15, the closing date for the election of candidates for membership whose names appeared in the March issue of "C.E.P.," all those listed were elected to the grades of membership indicated. In addition there were 111 Student members elected.

The Secretary reported that sixty-one Junior members had reached the age of 35 during the year 1952 and were no longer eligible for that grade of membership; they had neither accepted automatic transfer to Associate membership nor had they applied for Active membership. Therefore, these Junior memberships were discontinued as of Dec. 31, 1952.

F. L. Bruce, J. R. LaMar, C. L. Menzemer, and C. C. Young have en-

tered the Armed Forces and therefore were placed on the Suspense List at their request. G. S. Baldwin and R. M. McFarland completed their service in the Armed Forces and subsequently were restored to full participating membership.

Resignations were received from four members.

D. B. Keyes, W. L. McCabe, and F. J. Van Antwerpen were appointed as alternates to the regular representatives on the Perkin Medal Committee. Several appointments were made to the standing committees of the Institute upon recommendation of the chairmen. C. E. Ford was appointed Institute representative to attend the inauguration of G. Brooks Earnest as president of Fenn College on May 9.

Orders are being accepted for subscriptions to the 1953 Transactions of The Institution of Chemical Engineers (London). Schedule for quarterly publications is: July, 1953; October, 1953; January, 1954; April, 1954. Annual subscription is \$5.25.

## PEACETIME ATOMIC ENERGY

Establishment of Atomic Industrial Forum, Inc., an organization of businessmen, engineers, scientists, and educators interested in the industrial development and application of atomic energy for peaceful uses, was announced last month. Members of the board of directors are Albert L. Baker, Vitro Corp.; Walker L. Cislser, Detroit Edison Co.; John L. Collyer, B. F. Goodrich Co.; T. Keith Glennan, Case Institute of Technology; Frederick L. Hovde, Purdue University; Alfred Iddles, Babcock & Wilcox Co.; John A. Martino, National Lead Co.; John R. Menke, Nuclear Development Associates; Earle W. Mills, Foster-Wheeler Corp.; Mark E. Putnam, Dow Chemical Co.; Ross W. Thomas, Phillips Petroleum Co.; Howard G. Vesper, Standard Oil Co. (California); J. B. Woodward, Jr., Newport News Shipbuilding & Dry Dock Co.

Purposes of the association are free competitive development of atomic energy, the provision of a forum to resolve public atomic-energy problems, and dissemination of unclassified knowledge.

(More News on page 54)

## CANDIDATES

(Continued from page 50)

Gaede, Virgil E., Bartlesville, Okla.	Norton, George A., Northampton, Mass.
Garrett, Thomas F., Terre Haute, Ind.	Parker, Robert V., Texas City, Tex.
Gendel, Sydney Z., So. Euclid, Ohio	Parmer, John W., Velasco, Tex.
Gilliland, Joe E., Tulsa, Okla.	Patty, Paul L., Tuscumbia, Ala.
Hall, Donald R., Philadelphia, Pa.	Peters, John H., Wilmington, Del.
Huffman, Walter E., Oklahoma City, Okla.	Petry, Theodore A., E. Rockaway, N. Y.
Idczak, Leo R., Chicago, Ill.	P'Pool, Robert S., Ponca City, Okla.
Jackson, Robert C., Norwich, N. Y.	Pulver, Dale R., Painesville, Ohio
Jandacek, George W., Cushing, Okla.	Ratsep, Olev, New York, N. Y.
Kehm, Robert J., Louisville, Ky.	Ray, Joseph, New York, N. Y.
Kennedy, Thomas W., Hopewell, Va.	Read, James K., St. Simons, Ga.
Kosfeld, Otto R., St. Louis, Mo.	Riegel, Herbert, San Gabriel, Calif.
Kramer, Raymond F., St. Albans, N. Y.	Roche, Alfred J., Somers, Conn.
Lagakos, John G., Brooklyn, N. Y.	Rongren, Eric H., Chicago, Ill.
Maloney, Arthur P., Woodbury, N. J.	Rowe, James W., Akron, Ohio
Marrow, George W., Jr., Evanston, Ill.	Russell, C. M., Jr., New Orleans, La.
Mueller, Norman F., Stamford, Conn.	Saewert, Harold E., Park Forest, Ill.
O'Malley, Charles A., Detroit, Mich.	Schwaegerle, P. R., Elyria, Ohio
	Schwartz, Clarence E., Bridgeport, Conn.
	Scumas, Chris, Collingswood, N. J.
	Sherman, Morton, Evanston, Ill.

(Continued on page 54)

## SPRAY NOZZLES



### ... FOR LOWER COST

Spray Nozzles alone can often materially reduce spraying costs. Spraying Systems Co. has proved this again and again. Write for Catalogs 22 and 23 . . . and see for yourself.



### SPRAYING SYSTEMS CO.

3284 Randolph Street • Bellwood, Illinois

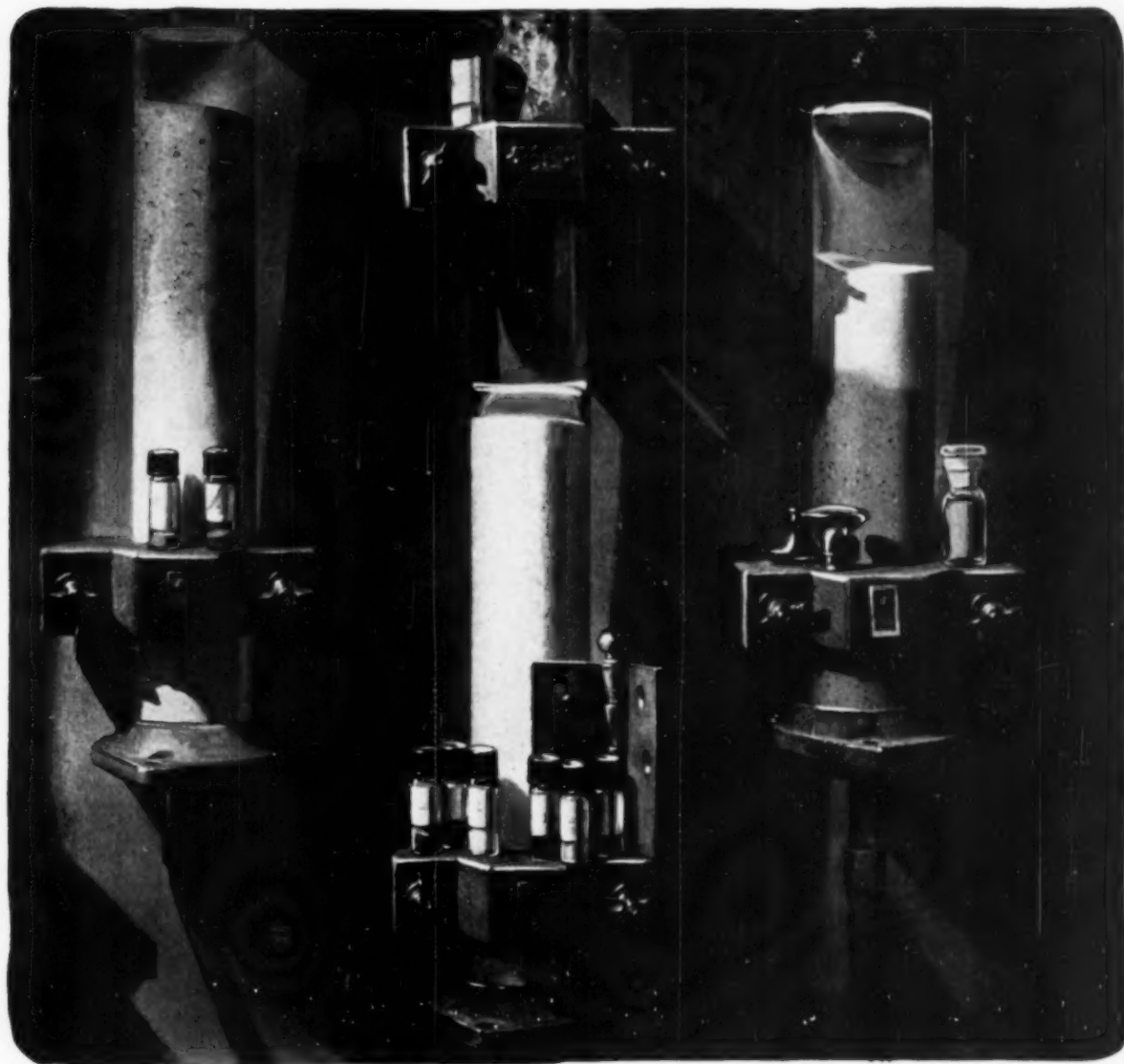
☐ Send me Catalog No. 22 ☐ Send me Catalog No. 23

Name \_\_\_\_\_

Company Name \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_



For want of a suitable recovery process, tons of valuable metals are discharged to waste each year. At best, this means economic loss; at worst, stream pollution. AMBERLITE ion exchange—a process which finds needles in chemical haystacks—often can obviate both problems.

The columns shown here will interest users of copper. They show how AMBERLITE® IRC-50, a cation exchange resin, efficiently adsorbs copper from solutions of its salts. Another cation exchanger, AMBERLITE IR-120, helps the rayon industry by

removing zinc from rinse water. The zinc is then re-used, and highly toxic wastes have been decontaminated.

There are many other examples: in electroplating, metal pickling, rare earth separations, and the processing of paper mill wastes. If your work involves such problems, or others in which dilute solutions of metallic salts occur, AMBERLITE ion exchange may offer you a new process, or a better one.

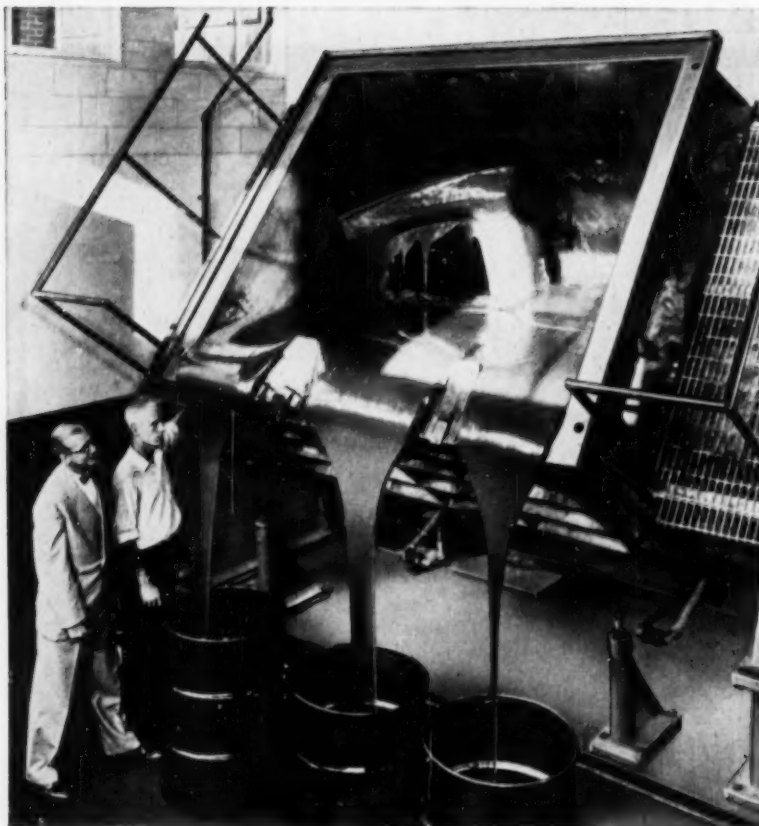
AMBER-HI-LITES, a bi-monthly report on ion exchange, is available on request.

## ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION



PHILADELPHIA 5, PENNSYLVANIA



## BAKER PERKINS builds world's largest color blending machine

Now in operation at the Hilton-Davis Chemical Company's plant in Cincinnati, this huge blender and flushing machine, designed and built by Baker Perkins Inc., mixes 1000 gallons of flushed colors at one time. That's roughly 15,000 to 30,000 lbs., depending on the specific gravity of the colors, nearly three times the capacity of any other blender in use today. The unit weighs 21 tons and took two years to design, construct and install.

You may not need the world's largest color blending machine, but you can't go wrong if you rely on the company that can build one. When you need good, dependable chemical mixing machinery that will help increase your production and keep your maintenance and operating costs low, it will pay you to consult a BAKER PERKINS sales engineer or write us today.

248-A

## BAKER PERKINS INC.

CHEMICAL MACHINERY DIVISION • SAGINAW, MICHIGAN

## NEWS

### PILOT PLANT FOR PUERTO RICAN RUM

A pilot plant for research in rum manufacture has been opened by the Agricultural Experiment Station, University of Puerto Rico. At a cost of \$500,000, the plant, which has a daily capacity of 150 proof gal., is an important factor in the government's research program to maintain Puerto Rico's preeminence as a rum-producing country.

The research program emphasizes development of new chemical methods of measuring the quality of rums, to supplement reports of tasting panels. With the new pilot plant available, every product and process involved in the production of rum will be carefully studied, even to the waste material obtained from the fermentation mash after its distillation, reported Arthur D. Little, Inc., designers and installers of the distilling unit.

A feature of the distilling unit, according to its designers, is the use of a graphic panel; a simplified flow sheet of the distillation operation is reproduced in color on the panel, to distinguish process units, the types of process, and utility lines. Instruments to indicate process variables are incorporated at the point on the control panel that corresponds to the point of measurement in the plant.

### AMERICAN ENKA TO PRODUCE NYLON

The Du Pont Co. announced that it has licensed American Enka Corp. to manufacture nylon textile fiber.

In June, 1951, Du Pont signed an agreement with The Chemstrand Corp., now completing a nylon plant in Pensacola, Fla. Both Enka and Chemstrand will be entirely independent producers with licenses covering the entire process.

(More News on page 56)

### CANDIDATES

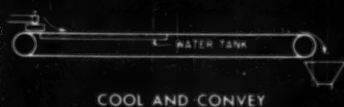
(Continued from page 52)

Shoptaw, G. H., Texas City, Tex.  
Silberberg, Harold, Austin, Tex.  
Starr, William C., Wilmington, Del.  
Summers, Richard S., Clayton, Mo.  
Trilling, Charles A., Havertown, Pa.  
Vandervoort, Kenneth L., Chicago, Ill.  
VanHynning, Norman D., Charleston, W. Va.  
Walters, Donald F., South Gate, Calif.  
Watson, J. W., Loudon, Tenn.  
Weidman, Fred H. D., Jr., Charleston, W. Va.  
Welch, Harry T., Glen Head, L. I., N. Y.  
Westbrook, Ezra J., Jr., Baton Rouge, La.  
White, Herbert M., Los Angeles, Calif.  
Wilson, S. R., San Francisco, Calif.  
Yuen, Hsiu Huo, Villanova, Pa.



Some of the functions that have been successfully performed by Sandvik Conveyors

**WITH A SANDVIK WATER-BED CONVEYOR YOU CAN:**



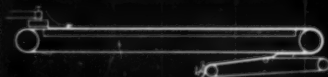
COOL AND CONVEY



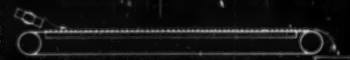
REGULATE THICKNESS WHILE COOLING  
(ANY THICKNESS UP TO 1" CAN BE COOLED)



CUT MATERIAL TO DESIRED SIZES  
WHILE COOLING



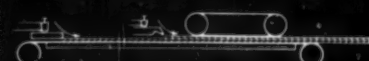
COOL AND STRIP OFF GELATINOUS  
MATERIALS IN SHEET FORM



COOL LOOSE AND PULVERIZED  
MATERIALS

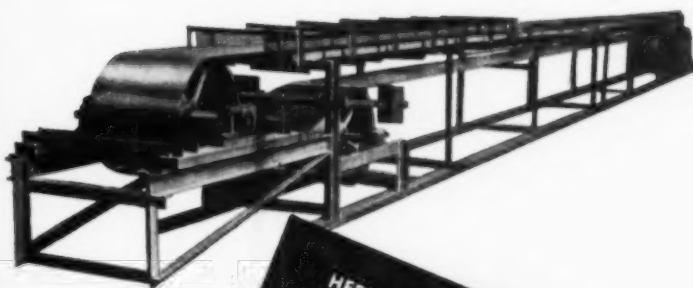


COOL SOLIDS IN SHEET FORM

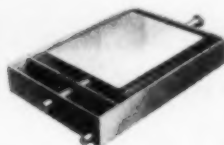


COOL MATERIAL IN LAYERS

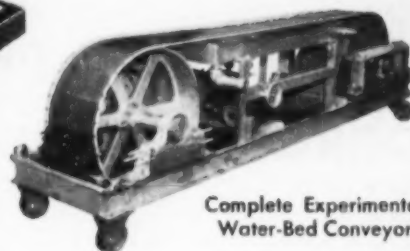
# HOW CAN SANDVIK'S CONTINUOUS STEEL-BELT COOLER Improve YOUR production?



HERE ARE TWO WAYS  
To "Pre-Test" Sandvik's  
Steel-Belt, Water-Bed Conveyor  
With Your Own Product



Water-Bed Section  
Test Tank



Complete Experimental  
Water-Bed Conveyor

With one of these experimental units you can find out how Sandvik's patented water-bed conveyor can make your processing more automatic.

A small scale trial in your plant will enable you to determine cooling rates and other pertinent data. You will see for yourself the extraordinary cooling capacity of this conveyor combined with the advantages of the steel belt.

**How The Water-Bed Conveyor Operates**—The loaded steel band "floats" along on an open trough of circulating water. The water pressure assures 100% coolant contact with the belt. The trough is so designed that no water can get on top of the belt.

*Experimental water-bed units are available on request. Sandvik's engineering department will help you decide which test unit is best suited for your purpose. Write, wire or 'phone for complete details.*

## SANDVIK STEEL, INC.

Conveyor Department  
111 Eighth Ave., New York 11, N. Y.  
WATKINS 9-7180

Manufacturers of Steel-Belt  
Conveyors For Over 30 Years



SS-64



## Solves Difficult Problems in CORROSIVE FUME CONTROL

Knight Pyroflex-Constructed Fume Washers are designed and built to handle corrosive gases and fumes of nearly every description. The unit shown above removes nitrating acid fumes from a plant which recovers industrial diamond dust. In this instance both a corrosive condition and a nuisance were eliminated.

Knight Fume Washers are essentially wet type scrubbers of compact and efficient design. Each unit is individually job-engineered. All service factors are considered including water consumption and fan power. Construction materials are selected according to corrosive factors involved. The result is a corrosion-proof, functional unit tailored to solve your particular problem. Although individually engineered, Knight Fume Washers are relatively low in cost and economical in operation.

Typical examples of Fume Washer applications include:

Plating fumes	Removal of chlorine fumes
Removal of hydrochloric acid fumes	Removal of dust from exhaust gas
Production of dilute muriatic acid	Cooling hot acid gases for processing
Suppression of oil and acid mists	Cooling and removing dust from gases

Write for Bulletin No. 9-F, Fume Washers

**Maurice A. Knight**

705 Kelly Ave., Akron 6, Ohio

**Acid and Alkali-proof Chemical Equipment**

## NEWS

### REMINGTON RAND OFFERS NEW ELECTRONIC BRAIN

Completely automatic control of industrial processing has made a large stride forward, according to executives of Remington Rand, Inc., by the development of ERA 1103, an automatic electronic digital computing system. The device has a large memory capacity; high speed (adding 16,700 ten-digit numbers in 1 sec.); and great programming versatility, being applicable primarily to scientific-mathematical computation and also to air-traffic control, air defense, aircraft design, automatic data reduction, and general industrial and economic planning. It is adaptable to a variety of input-output signals, such as magnetic tape, radar signals, teletype communications circuits, card readers, photoelectric tape readers, analogue-digital converters, card punches, electric typewriters, high-speed tape punches, process-actuating mechanisms, graphic visual displays, or high-speed tabulators.

The computer weighs 10 tons, is 54 ft. long by 20 ft. wide, has 4500 tubes and a built-in air conditioner, and uses punch paper tape fed to a magnetic drum. The first unit will go to the Department of Defense, and commercial production is scheduled for March, 1954. The machine costs \$850,000 and may be purchased or rented.

### NUCLEAR ENGINEERING AT BERKELEY

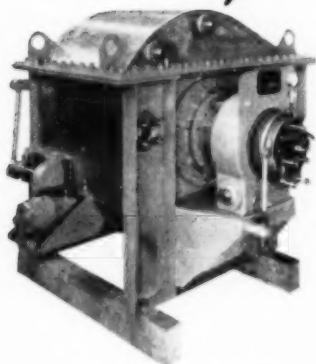
A 3-day conference on nuclear engineering will be held at the University of California, Berkeley, from September 9 to 11, 1953. Sponsors of the conference will be the Departments of Engineering at Berkeley and Los Angeles; the Northern California sections of A.I.Ch.E., A.I.E.E., and A.S.M.; the Southern California sections of A.S.M.E., A.I.Ch.E., and A.S.M.; and the Committee on Atomic Energy Education of A.S.E.E.

It is expected that the program will be concerned with technical and engineering-economic studies of nuclear power plants, other reactors, and isotope production, separation, and applications. Presentation of papers on these and related topics is invited. Each person wishing to present a paper should submit the title and an unclassified 200-word abstract to Prof. R. A. Fayram, 208 Mechanics Building, University of California, Berkeley 4, Calif. The deadline announced for these abstracts is May 18, 1953.

(More News on page 58)

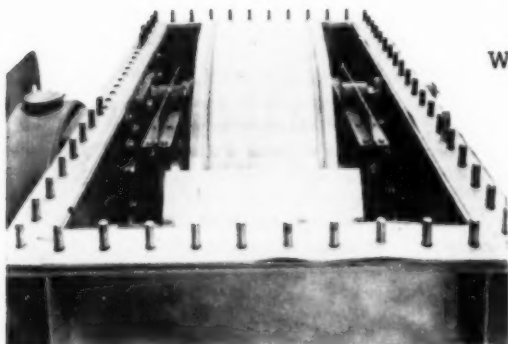
# A COMBINATION OF CORROSION PROBLEMS —all solved with *Carpenter* materials

*sulphuric acid, nitric acid and  
potassium permanganate safely  
handled by Stainless #20*



The materials handled by this continuous vacuum filter are not only corrosive but toxic. The principal corrodent in the filtrate is sulphuric acid (PH1). The solutions used for periodic cleaning of the filter are nitric acid and potassium permanganate.

To withstand this combined attack, all parts of the filter that come in contact with slurry, cake or filtrate are made from Carpenter Stainless #20—sheet, pipe, nipples, electrodes, rounds, etc. The hood to contain the gases is made from Carpenter stainless sheet, type 316.



Wherever corrosion is a problem, it will pay you to get in touch with your nearby Carpenter Distributor. He can put at your disposal our 25 years of experience in providing materials to withstand corrosion and the necessary "know-how" to fabricate them easily. The Carpenter Steel Company, Alloy Tube Division, Union, N. J.

Export Dept.: The Carpenter Steel Co., Port Washington, N. Y. "CARSTEELCO"



#### New 16-Page Book of Technical Data

For complete information on No. 20 and the jobs it can do, write us a note on your company letterhead and ask for the new Carpenter Stainless No. 20 book.



# Carpenter

## STAINLESS TUBING & PIPE

Analysis

Tolerance

Finish

— guaranteed on every shipment

# If your process requires the valving of "hard-to-handle" fluids...



**HILLS-McCANN**  
*Saunders Patent*  
diaphragm valves  
provide  
the answer

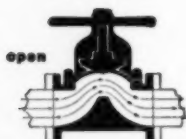
**Leakproof valving of air . . .  
corrosive materials . . . slur-  
ries . . . solids . . . volatile and  
viscous substances**

Hills-McCanna Diaphragm Valves can eliminate the problems involved in valving many of the so-called "hard-to-handle" fluids. By employing a simple pinch clamp principle, Hills-McCanna valves put an end to leakage, repacking and contamination.

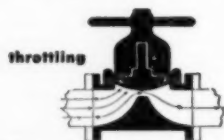
Hills-McCanna Valves are available handwheel or lever operated or for operation by pneumatic or hydraulic cylinders, diaphragm motors, electric motors, etc. Choice of 14 diaphragm materials, 49 body materials. Sizes from 3/8" to 14". Suitable for pressures to 150 psi., temperatures to 180° F. (higher with special materials). Screwed or flanged connections.

Write for Catalog V-52, **HILLS-McCANN CO.**, 2438 W. Nelson St., Chicago 18, Ill.

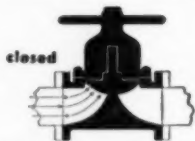
**THIS SIMPLE PRINCIPLE  
ASSURES POSITIVE  
LEAK TIGHT  
VALVING**



Compressor is raised, lifting diaphragm by means of a stud molded into the material.



Compressor and diaphragm partially lowered. Compressor design guides and supports diaphragm.



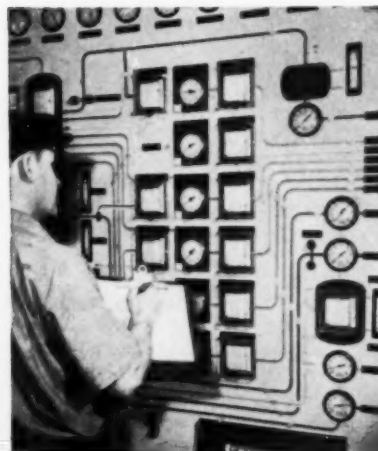
Compressor presses diaphragm tightly against weir, pinching off flow and making a tight seal.

**HILLS-McCANN**

*Saunders Patent diaphragm valves*

**Also Manufacturers of Proportioning Pumps  
Force Feed Lubricators • Magnesium Alloy Castings**

## VISCOSITY MEASURER PRODUCED BY BENDIX



Instrument panel of a huge petroleum-fractionating column at the Sun Oil Company's Marcus Hook refinery. Dials in the center column are the visual end of a new "ultrasonic dip-stick" controlling production of lubricating oils and many other types of fluids. Produced by Bendix Aviation Corp., the new device, called the Ultra-Viscoson, "feels" fluids with a thin probe and tiny pulse of energy—about one-millionth the power of a flashlight—and instantly shows their flowability on dials and moving charts. Here a Sunoco plant operation observes exact heaviness of oil from several points in refinery tower.

An instrument for measuring and controlling viscosity by ultrahigh-frequency sound waves has been announced by Bendix Aviation Corp. Designed for permanent installation in a pipeline, kettle, or fractionating tower, the Ultra-Viscoson consists of a probe, which is immersed in the liquid under test, and an electric computer. The probe is a thin alloy-steel blade which is "excited" by ultrasonic energy equivalent to only one-millionth the power of an average flashlight. Vibration of the blade is affected by the viscosity of the fluid with which it comes in contact, and the computer transmits the vibrations as a viscosity curve on a recorder. The instrument, according to its producers, can operate in high-pressure or vacuum containers in a heat range from -200° to 650° F. and measures liquids, slurries, and some fine powders.

An important factor, the Bendix executives say, is the time-saving quality of the Ultra-Viscoson, which they maintain records in a fraction of a second tests that require up to 3/4 hr. by batch-taking and laboratory-analysis methods. This is particularly useful, they stress, when fluids continuously change in viscosity during processing. Besides its industrial applications, the new instrument can measure instantaneously the clotting time of human blood and, according to Bendix officials will be of use in the study of blood diseases.



Cuno-Type FKR filter with bonnet removed to show two Ni-Resist cages wrapped with stainless steel wire. Ni-Resist components were cast by THE TAYLOR & FENN COMPANY, Windsor, Conn. The first Flo-Klean filter unit manufactured by the CUNO ENGINEERING CORP., Meriden, Conn., and installed nearly 14 years ago, is still in operation.

# CUNO ENGINEERING uses NI-RESIST

**BECAUSE  
No Other Cast Metal  
Provides Such a  
Unique Combination of  
Useful Engineering  
Properties**



NI-RESIST® is a highly nickel-alloyed iron that provides a unique combination of properties at moderate cost . . .

It resists corrosive attacks of *acids, alkalies and salts* and is highly resistant to galling and metal-to-metal wear.

Its wear-resistance, combined with inherent resistance to corrosion, makes Ni-Resist ideal for curbing erosion by liquids and slurries.

To these properties add ready machinability, and it is evident why the vital cylindrical cartridge cores of Cuno Flo-Klean Filters are cast in Ni-Resist.

Several types of Ni-Resist are available to meet a variety of industrial demands. Get full information . . . mail coupon now.

At the present time, nickel is available for the produc-

tion of Ni-Resist and other alloys containing nickel, for end uses in defense and defense supporting industries. The remainder of the supply is available for some civilian applications and governmental stockpiling. There are authorized producers, from coast to coast, equipped to produce Ni-Resist castings in all common forms and shapes.

**THE INTERNATIONAL NICKEL COMPANY, INC.**  
Dept. 20, 67 Wall Street, New York 5, N. Y.

Please send me booklets entitled, "Engineering Properties and Applications of Ni-Resist," and "Buyers' Guide for Ni-Resist Castings."

Name \_\_\_\_\_ Title \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_

**THE INTERNATIONAL NICKEL COMPANY, INC.** 67 WALL STREET  
NEW YORK 5, N. Y.

# Explaining the Why and How of Admissions

L. C. Kemp, Jr. Chairman, Committee on Admissions

**S**ECTION 1, Article VI of the Constitution and Code of Ethics of the American Institute of Chemical Engineers requires that a Committee on Admissions—"See that only the names of qualified applicants are recommended to Council for election." Further, it is specified that "... The Committee shall use its best judgment in evaluating the training, accomplishments and experience of each applicant resorting where necessary to the doctrine of equivalents, while maintaining the standards for qualification set forth in Article III, Sections 2, 3, 4 and 5."

The members of the Institute have, through the Constitution, clearly circumscribed the scope of the responsibility of the Committee on Admissions. This Committee has neither the authority nor the responsibility for establishing or changing qualifications for the various grades of membership. The business of the Committee on Admissions is solely that of determining, with the information available to it, whether an applicant does or does not meet the requirements for the particular grade for which he has applied.

## Experienced Men Serve

To bring experience and judgment to the job, the services of twenty-four Active members of the Institute have been obtained. These men are successful chemical engineers. They were selected because of their interest and their willingness to put in the amount of time necessary for the Committee's work. In selection of Committee members, care is taken to maintain representation from as wide a group of chemical engineering occupations as possible. Among the members of the present Committee, there are two who are engaged in full-time teaching jobs. There are four other members of the Committee who entered industrial work after they had held important chemical engineering teaching positions for many years. Several members of the Committee are engaged in selling. Other members are drawn from a variety of industries and are engaged in many different activities.

In addition to the bases for selection of Committee members just discussed, some effort is made to obtain representation from as many sections throughout the country as possible. The constitutional requirement that six members

## EDITOR'S NOTE

In the past, Chemical Engineering Progress has presented one-page summaries of important work done by local sections. This present article is a logical continuation of that series, and it institutes what we hope will be a continual report to the members on the work of the A.I.Ch.E. committees. We hope through them to reach members and inform them on the virility and dynamism of our profession. Particularly do we wish to call attention to the April editorial by Carl C. Monrad, which is also an account of a committee activity. We want to hear from the members on this and encourage their letters and suggestions as to what particular activity they would next like to hear about.

of the Committee are needed for a quorum makes it essential that a fairly high percentage of the members reside within a reasonable traveling distance of New York, but more distant points have not been neglected. California, Texas, Missouri, Ohio and Illinois are now represented. These members from the outlying areas have a surprisingly good attendance record, and they contribute much to the work of the Committee by making investigations on applicants from their areas.

The principal work of the Committee is carried out at its monthly meetings. At these meetings, which are from four to six hours in length, most of the time is devoted to consideration of the applications for Active membership. For each applicant, the Secretary's office provides a separate file containing all papers on the case. A letter is obtained from the applicant's college or colleges as a confirmation of the degrees claimed and listed by the applicant. Reference questionnaires are available from each of the persons designated by the applicant, including those listed as being his immediate superior in each position held.

All available information is considered by the Committee, and particular attention must be given to the three critical questions:

Is the applicant actively engaged in chemical engineering?

Has he had the required years of experience in chemical engineering?

Has he had the required number of years of responsible charge?

The Constitution now permits a somewhat broader interpretation of work which can be included in the chemical engineering category. Positions in patenting, in sales, in management and in a number of other fields can provide experience credit if it is established that a substantial amount of chemical engineering practice is involved.

## Meaning of Responsible Charge

The establishment of the *responsible charge* period seems to be the most troublesome. The Constitution says that "Responsible charge . . . means individual professional responsibility for important work in chemical engineering." The Committee has recognized that an adequate degree of responsibility might be involved even though the applicant had no one working for him. The Committee does regard it as essential, however, that the responsibility for important chemical engineering work be well documented in the reference replies.

The Committee encounters considerable difficulty with applications from the educational field. For many years the Constitution required that credit for responsible charge be given only for actual chemical engineering practice as distinguished from the teaching of chemical engineering. This is no longer the case, and it is believed that under the present rules the Committee is able to give the academic people consideration on a basis fully comparable to that accorded applicants from industry.

The Committee's problems arise primarily from lack of information and from misinformation provided by the references. In the case of nonmembers, this is not always difficult to understand and condone. In the case of Institute members, particularly Active members, it is inexcusable. Failure of the references to provide answers to important questions, such as those involving the extent of the applicant's responsible charge leaves the Committee without a basis of judgment. This requires either, or both, a special investigation by a Committee member or further correspondence with the references. The action is thus delayed, and the ultimate result may be a denial, since the only reasonable inference which can be

(Continued on page 62)

# A Progress Report on the Status of FluoSolids

## *Applications of Non-Catalytic Fluid Techniques Expanding into Many New Fields*

Pioneered by Standard Oil Development Company during World War II, fluidization is today widely recognized as an ideal means of promoting intimate contact between solids and gases. As licensee in all non-catalytic non-hydrocarbon fields, The Dorr Company has continually expanded the applications of this new technique since 1944. At the present time, FluoSolids is demonstrating outstanding advantages in the processing of a wide variety of metallic and non-metallic minerals, and holds great promise for the future in other fields not yet fully developed.

### **GOLD**

One of the first applications of the Dorrco FluoSolids System was the roasting of arsenopyrite gold ores prior to cyanidation, and several installations have been operating with marked success for two to five years. Latest development for gold roasting is the split compartment Reactor. In this type of unit, preliminary reducing conditions are provided in one half of the Reactor and a complete oxidizing roast in the other, resulting in decreased cyanide consumption and better metallurgy at the mill.

### **PYRITE**

The sulfur shortage has contributed to great activity in the pulp and paper field. Eight FluoSolids Systems in the U. S.,

Canada and Norway are either in operation or under construction in sulfite pulp mills, for the production of  $\text{SO}_2$  for cooking liquor. Eight more are in operation or being installed to produce  $\text{SO}_2$  from pyrite, pyrrhotite and low grade sulfur ores at acid plants, which will produce over 1200 tons per day of  $\text{H}_2\text{SO}_4$  by the contact method. This impressive record results directly from the fact that FluoSolids can deliver a high strength  $\text{SO}_2$  gas at lower investment and operating costs than conventional roasters and provides users with an economically feasible and reliable source of  $\text{SO}_2$  despite fluctuations in natural sulfur supply.

### **ZINC**

The first commercial FluoSolids installation for the roasting of zinc concentrate went into operation in the summer of 1952. It is producing  $\text{SO}_2$  gas for sulfuric acid manufacture and a desulfurized zinc calcine for leaching, prior to electrolytic zinc production. Results to date have demonstrated marked simplicity of control and operation, and two other zinc producers have ordered similar Systems.

### **COPPER**

More recently, the first FluoSolids System to provide a sulfating roast to a copper-zinc concentrate went into operation. In this application, close operating con-

trols make it possible to render the valuable base metals soluble and, at the same time, minimize solubility of the iron. This permits high recoveries of copper and zinc by leaching. When followed by electrolytic precipitation, economic advantages are indicated under many conditions as compared with conventional smelting practice.

### **NEW DEVELOPMENTS**

Studies to explore the utilization of FluoSolids for the beneficiation of low grade iron ore are now being conducted. In this operation, hematite is given a reducing roast to convert it to magnetite for subsequent concentration by wet magnetic means. Higher unit recovery of iron and the production of better concentrate grades indicates improved economics as compared with other beneficiation methods.

Among the other numerous fields currently under investigation are the calcination of alumina, the reburning of precipitated lime sludge and the self roasting of low grade sulfur ores.

If you would like more information on FluoSolids — the most significant advance in roasting technique in the last 30 years — write The Dorr Company, Stamford, Conn. or in Canada, The Dorr Company, 26 St. Clair Avenue East, Toronto 5.

*FluoSolids is a trademark of The Dorr Company, Reg. U. S. Pat. Off.*

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## ADMISSIONS COMMITTEE

(Continued from page 60)

drawn from repeated failure of a reference to answer with respect to responsible charge is that there is a reluctance to give unfavorable information.

In not a few cases, applicants have used members who are no more than casual acquaintances as references. Such references are productive of little useful information to the Committee unless they take the trouble to make some specific inquiry as to the qualifications of the candidate. Such information may be obtained from employers or on-the-job associates by judicious inquiry.

It is important that members fully realize that the information they provide on the reference sheets constitutes the bulk of the evidence on which an applicant's suitability for membership is judged. Statements to the effect that the applicant is "a fine fellow," "a brilliant student," etc., are of little value to the Committee. Particular attention should be given to providing reliable information on applicant's current engagement in *chemical engineering*, and extent of *chemical engineering* experience. Any unfavorable comments should be complete enough to permit the Committee to make some judgment of the seriousness of the matter.

In spite of the sincere effort to treat all applications on a fair and equitable basis, the Committee may make some mistakes. These are usually caused by lack of adequate data or by misinterpretation of the available information. The Committee stands ready at all times to review its actions and to correct any errors.

The chairman thanks the members of the Committee for their time and efforts in furthering this article. Appreciation is rendered here to A. J. Weith, the Adviser, the vice-chairmen, Messrs. Stritzli and Stratton, and R. P. Kite, Council representative, for their help on matters of policy discussed in this review.

## NEW GLOSSARY OF MANAGEMENT TERMS

A Glossary of Terms Used in Methods, Time Study and Wage Incentives has recently been published by the Society for Advancement of Management. Containing 332 definitions, it is described as representing the work of ninety-three management leaders in the fields of cost accounting, time study, wage planning and administration, arbitration, method engineering, sales planning, and personnel practices. The glossary is in vest-pocket format and may be purchased for \$1 from the Society for Advancement of Management, 411 Fifth Avenue, New York 16, N. Y.



## LOCAL SECTION

More than 200 chemical engineers and other industrialists attended the Third Technical Symposium of the Boston Section Ichthyologists held on April 8, at John Hancock Hall in the afternoon, and at the University Club in the evening. Titled "Can New England Expand Its Basic Chemical Industry?" the symposium was constituted as a stockholders and board of directors meeting to consider the economic prospects for an ammonia plant in New England.

In the evening session, Richard Preston, Department of Commerce, Commonwealth of Massachusetts, gave a talk titled "What Massachusetts Can Do for Industry."

Four papers were presented in the afternoon session as follows:

**SELECTION OF AMMONIA AS A SPECIFIC CASE STUDY** by Charles A. Stokes, Godfrey L. Cabot, Inc.

**MARKETS FOR AMMONIA AND AMMONIA-BASED CHEMICALS IN NEW ENGLAND** by Christian J. Matthew, Arthur D. Little, Inc., and Robert Vaughn, Godfrey L. Cabot, Inc.

**AN ANALYSIS OF TRANSPORTATION PROBLEMS AFFECTING LOCATION OF AN AMMONIA PLANT IN NEW ENGLAND** by Robert Edgar, Boston and Maine Railroad, and Harry R. Marty, Dewey & Almy Chemical Co.

**PROCESS DESIGN AND ECONOMICS OF AN INTEGRATED AMMONIA AND AMMONIUM-BASED CHEMICALS PLANT IN NEW ENGLAND** by Robert L. James, Arthur D. Little, Inc., and Roger D. Newton, Badger Manufacturing Co.

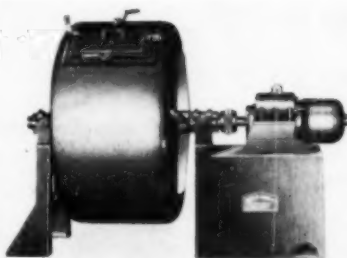
The Terre Haute Section, in cooperation with the chemical engineering department, Rose Polytechnic Institute, has scheduled a Bio-Engineering Symposium for May 23 at Rose Polytechnic Institute, Terre Haute, Ind. More details on this one-day meeting can be found on page 28 of this issue.

The March meeting of the Southern California Section was attended by approximately 120 members and guests. W. E. Hanford, vice-president in charge of research, M. W. Kellogg Co., was speaker of the evening.

Dr. Hanford, as an authority on high pressure reactions, reviewed about fifty organic reactions of such materials as ethylene, acetylene, carbon monoxide, and Fluorocarbons. The relationships between these unsaturated components, general methods of catalysis, yields, and side reactions were outlined and discussed.

Some humorous incidents, describing many of the practical difficulties which were encountered in some of the recent developments in the field, were mentioned.

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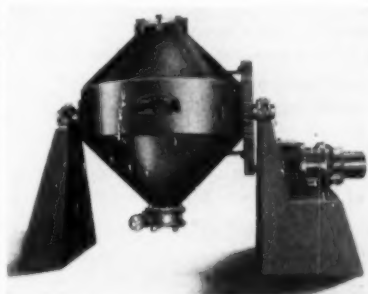
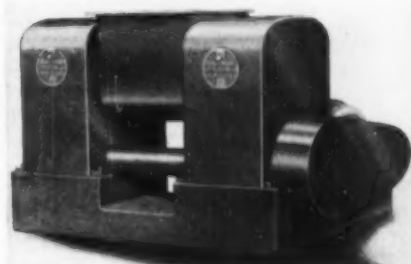


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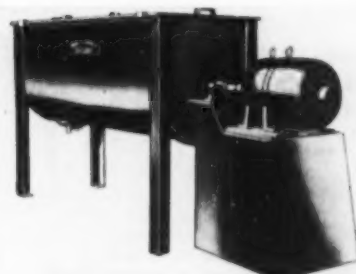
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The Section, according to Gale Peterson, is planning some field trips for this summer. First, will be a week-end excursion by chartered bus to the American Potash & Chemical Co.'s installations at Trona, Calif. Also a day tour is under consideration through the Kaiser steel mill in Fontana.

The Cleveland Section's general meeting began informally on March 24 in the Oak Room at Fenn College. Wilfred H. Charbonnet, reporter, states that the meeting was the largest in attendance ever held. Don Q. Kern, director of engineering, chemical and process equipment division, Colonial Iron Works, talked entertainingly and non-mathematically on "Design Optima and Thermal Calculations."

Officers for 1953-54 season year were elected at the April 14 meeting of the Philadelphia-Wilmington Section. E. R. Westfield and W. E. Osborn sent in information: Roy A. Kinckiner was named chairman for the coming year while W. T. Dixon was elected chairman-elect. Mr. Kinckiner is deputy director, engineering research laboratory, engineering department, Du Pont Co., and Dixon is manager, design division, engineering and construction department, Atlantic Refining Co. Other officers elected were: W. E. Osborn, Atlantic Refining Co., corresponding secretary; T. A. Burtis, Houdry Process Corp., recording secretary; W. A. Bours, Du Pont Co., treasurer; H. L. Bolton, Philadelphia Quartz Co., assistant treasurer. Elected to the executive committee were the outgoing chairman, W. E. Chalfant, Atlantic Refining Co., J. I. Harper, Sun Oil Co., K. C. Laughlin, Hercules Powder Co., and J. A. Gerster, University of Delaware.

Dudley Thompson, associate professor of chemical engineering, Virginia Polytechnic Institute, presented an invited, illustrated lecture on "Applied Ultrasonics" before the Joint Council of Engineers and Architects of Savannah on May 20, at the Savannah Hotel. The Coastal Georgia Section of A.I.Ch.E., which has recently been granted a charter by the National office, was the host organization.

Professor Thompson's talk dealt with the nature of ultrasonic waves, the methods and equipment for producing this form of energy, and some of the principal effects that are caused by ultrasonic energy.

On Tuesday, March 17, 1953, the New Orleans Section of the A.I.Ch.E. held its annual joint meeting with the Tulane Chapter of A.I.Ch.E. The meeting was attended by fourteen members of the New Orleans section, eight student members and two nonmembers. J. H. Bryant reported on the meeting as follows:

Leon Godchaux, II, who was co-chairman with the Baton Rouge Section of the Biloxi meeting of A.I.Ch.E., gave a summary of the activities at the Biloxi meeting.

Ray Sims, president of the Student Chapter, delivered a report on "Going from Laboratory to Pilot Scale in Producing Polystyrene." The Tulane Student Chapter constructed and exhibited a pilot scale vessel for production of polystyrene at the annual "Engineer Review" on the Tulane University Campus. This review is staged annually, principally for the benefit of the high school students in New Orleans who are considering pursuing an engineering curriculum.

Robert Wooten of the Tulane Student Chapter discussed the recent activities of the chapter, which include presentation of papers on water treating and the processing of Carbide chemicals, field trips to Port Sulphur and the Flintkote Co., and participation in the Engineering Review.

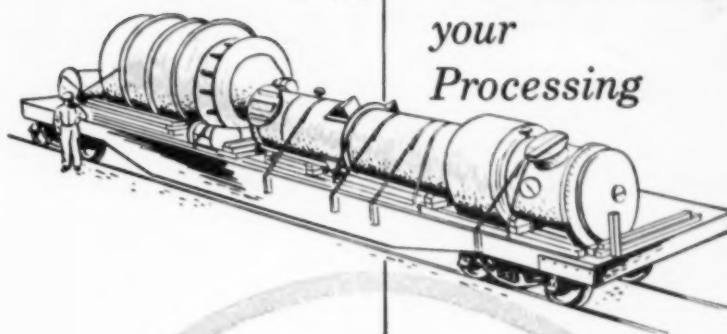
Alfred Hiller of the Tulane Student Chapter presented a paper on solvent extraction and discussed the latest methods used in this industry.

The Louisville Section was honored on April 14 by the presence of A.I.Ch.E. President W. T. Nichols, who discussed many matters and sundry before the members at the Speed Scientific School Auditorium in Louisville, Ky.

The Tulsa Section held a meeting on March 16 in the Blue Room of the Alvin Hotel. Paul R. Schultz, manager of economics department, Stanolind Oil & Gas Co., gave a talk titled "Review of NPC Report on Synthetic Fuels." Ray J. Stanclift, Jr., reporting on the meeting, said that it was in 1951 that the Secretary of the Interior requested the National Petroleum Council to review the cost estimates made by the Bureau of Mines for the production of synthetic fuels. The results of this complete study were covered by Mr. Schultz in his address.

The Akron Section met April 23 at the Y.M.C.A. Social Hall to hear Nelson Taylor, Minnesota Mining & Manufacturing Co., discuss "Fluorochemicals—New Materials for Industry." W. M. Otto, reporter of the Section, explains that Fluorochemicals is the term for an entirely new class of compounds which are produced by Minnesota Mining & Manufacturing Co. by the electro-chemical fluorination process. He covered both inert and reactive Fluorochemicals including a wetting agent which is more surface active than any organic detergent. Dr. Taylor has held teaching and administrative positions at the University of Minnesota and Pennsylvania State College, and at present is manager of the Fluorochemicals department for the 3M company.

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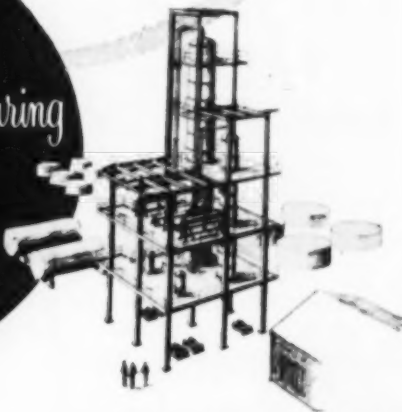
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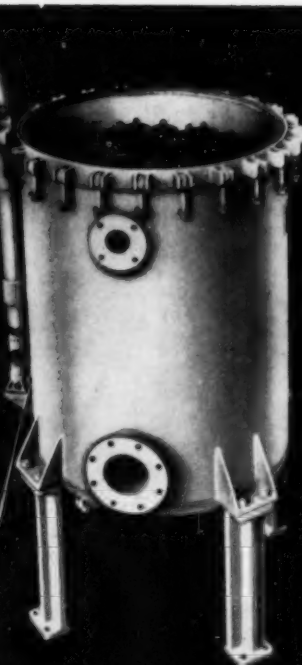
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The seventh meeting of the Pittsburgh Section was held at the Royal York Apartments on April 1, 1953.

E. A. Sanford, director of research, Pfaudler Co., spoke about the fabrication, uses, and limitations of glass-lined process equipment.

Mr. Sanford began his discussion by tracing the history of the company to illustrate the development of the glass-lined equipment industry. The principal early market for such equipment was the beer industry, which used glass-lined fermentation tanks. This market was lost when prohibition came. The company then made equipment for the dairy and food industries and later became interested in corrosion-resistant equipment of all types. Repeal of prohibition and World War II revived and broadened the market for glass-lined equipment.

The meeting was reported by Messrs. West, Morrissey, and Black.

"Fluid Flow and Mixing" was the title of an address given by J. H. Rushton, professor and director of chemical engineering, Illinois Institute of Technology, Chicago, Ill., before the Knoxville-Oak Ridge Section on April 9. The Section is planning a Ladies' Night to be held in May in Knoxville. Stuart Fonde, Knoxville building contractor, is scheduled to discuss "New Trends in Housing."

The T. E. Wannamaker Co. was organized in 1937 with a capital of \$12,000. It started with the manufacture of organic chemicals, produced tetryl during the war and then produced custom chemicals. In this vein, Dr. T. E. Wannamaker, president of T. E. Wannamaker, Inc., Orangeburg, S. C., began his talk on small chemical business at the March 19 meeting of the New York Section. B. S. Rosen, reporter of the New York Section, states that an interesting question and answer period followed the conclusion of the talk.

John H. Smithson spoke before the New Jersey Section on "Oxidation of Hydrocarbons," on April 14, 1953, at the Celanese Research Center, Summit, N. J. He discussed important technical and economic aspects of the controlled oxidation of propane and butane. L. J. Heney, reporter, informs us that Mr. Smithson, who is with the chemical division of Celanese, received his A.B., B.S., and M.S. from Columbia University, and joined the Celanese Corporation when the chemical division was established in 1946.

Messrs. Kerlin and Nellums have reported on the March 24 meeting of the St. Louis Section. At this meeting R. W. Kolderman, manager of the Chicago office, Dow-Corning Corp., talked on "Silicones—New Engineering Materials." The meeting was held at recently dedicated Louderman Hall at Washington University. Senior chem-





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ical engineering students from Wash-  
ington University, University of Mis-  
souri, and the Missouri School of Mines  
and Metallurgy were special guests of  
the Section. The constitution of the  
Section was amended to change election  
time from fall to spring. Therefore, next  
election will be in March, 1954, with  
transfer of offices in May, 1954.

At the March 17, 1953, meeting of the  
Charleston Section, held at the Charleston  
Recreation Center, 123 members and guests were  
present.

The speaker for the evening, G. C. Thrift,  
engineering manager, Koch Engineering Co.,  
Wichita, Kan., was then introduced. His sub-  
ject was "The Development of the Kascade Tray."  
He recalled that in the early days of the petro-  
leum industry the standard packing was  $\frac{3}{4}$ - to  
 $1\frac{1}{2}$ -in. stone. Early attempts to use bubble trays  
were not successful because they were not  
adapted for the high L/G ratios employed. The  
Kascade tray was developed for that particular  
condition.

Mr. Thrift then compared the original Kascade  
tray with more recent designs in which energy  
recovery on a tray has been increased to 84-  
92% compared to the previous value of about  
44%. This improvement which has been brought  
about by employing a Venturi-type flow rather  
than an orifice-type slot action has resulted in  
decreased pressure drops.

A. G. Draeger, Charleston reporter, states  
that the talk was illustrated with a number of  
blackboard illustrations including L-V diagrams  
showing the operating area of the various types  
of Kascade trays as compared to bubble trays  
and packed columns.

The thirty-seventh general meeting of  
the East Tennessee Section was held on  
March 25 in the Foreman's Room, Ten-  
nessee Eastman Co. Toy F. Reid, sec-  
retary-treasurer of the section, reporting  
on the meeting, states that W. D. Ken-  
nedy, senior research chemist, Tennessee  
Eastman Co., spoke on the uses of  
atomic energy, both present and future.  
Dr. Kennedy, a former research super-  
visor at the Underwater Explosives Re-  
search Laboratory at Woods Hole  
Oceanographic Institution, reviewed the  
current use of atomic energy as a wea-  
pon, a research tool, a medical aid, and  
as a source of industrial energy.

Edwin Blase of Chas. Pfizer & Co., Groton,  
Conn., has accepted the 1953 chairmanship of  
the publicity committee of the Eastern Connecti-  
cut Chemical Engineers' Club and will keep us  
posted on the activities of that club. So says  
R. C. Berry, who was temporary chairman of  
the publicity committee. On March 25 a joint  
meeting was held with the New London Section  
of the A.S.M.E. at which A. F. McKee, of the  
electric boat division of General Dynamics Corp.,  
discussed his profession, the raising of sunken  
submarines.

—H.R.G.

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## FUTURE MEETINGS AND SYMPOSIA OF A.I.Ch.E.

Chairman of the A.I.Ch.E. Program Committee  
Loren P. Scoville, Jefferson Chemical Co.

260 Madison Ave., New York 16, N. Y.

### MEETINGS

**San Francisco, Calif.**, Fairmont Hotel, Sept. 13-16, 1953.

TECHNICAL PROGRAM CHAIRMAN: R. W. Moulton, Head, Dept. of Chem. Eng., University of Washington, Seattle, Wash.

**Annual—St. Louis, Mo.**, Hotel Jefferson, Dec. 13-16, 1953.

TECHNICAL PROGRAM CHAIRMAN: R. M. Lawrence, Monsanto Chem. Co., St. Louis 4, Mo.

**Washington, D. C.**, Statler Hotel, March 8-10, 1954.

TECHNICAL PROGRAM CHAIRMAN: George Armistead, Jr., Consult. Chem. Eng., George Armistead & Co., 1200 18th St. N.W., Washington 6, D. C.

**Springfield, Mass.**, Hotel Kimball, May 16-19, 1954.

TECHNICAL PROGRAM CHAIRMAN: E. B. Fitch, Asst. to Res. Dir., The Dorr Co., Westport, Conn.

**Ann Arbor, Mich.**, Univ. of Mich., Ann Arbor, Mich., June 20-25, 1954—Conference on Nuclear Engineering.

TECHNICAL PROGRAM CHAIRMAN: D. L. Katz, Chairman, Dept. of Chem. and Met. Eng., Univ. of Mich., 2028 E. Eng. Bldg., Ann Arbor, Mich.

**Glenwood Springs, Colo.**, Hotel Colorado, Sept. 12-16, 1954.

TECHNICAL PROGRAM CHAIRMAN: Prof. C. H. Prien, Dept. of Chem. Eng., Univ. of Denver, Denver 10, Colo.

**Annual—New York, N. Y.**, Statler Hotel, Dec. 12-15, 1954.

TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

### SYMPOSIA

Industrial Research, Pittsburgh 13, Pa.  
MEETING—St. Louis, Mo.

#### Heat Transfer

CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).

MEETING—St. Louis, Mo.

#### Carbonization

CHAIRMAN: R. S. Rhodes, Asst. Mgr., Prod. Dept., Koppers Co., Inc., Koppers Bldg., Pittsburgh 19, Pa.

MEETING—St. Louis, Mo.

#### Industrial Waste Disposal

CHAIRMAN: K. S. Watson, Coordinator, Waste Treatment, Mfg. Facilities Serv. Dept., Gen'l. Electric Co., 202 State St., Schenectady, N. Y.

MEETING—St. Louis, Mo.

#### Nuclear Engineering

CHAIRMAN: D. L. Katz, Chairman (Address: See Ann Arbor Meeting).

MEETING—Ann Arbor, Mich.

#### Reaction Kinetics

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—New York, N. Y.

#### Liquid Entrainment and Its Control

CHAIRMAN: H. E. O'Connell, Ethyl Corp., P. O. Box 341, Baton Rouge, La.

#### Absorption

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

#### Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

#### Nucleation Processes

CHAIRMAN: E. L. Piret, Dept. Chem. Eng., Univ. of Minn., Minneapolis 14, Minn.

#### Ion Exchange

CHAIRMAN: N. R. Amundson, Dept. of Chem. Eng., Univ. of Minnesota, Minneapolis 14, Minn.

MEETING—San Francisco, Calif.

#### Mixing

CHAIRMAN: J. H. Rushton, Dept. of Chem. Eng., Illinois Inst. of Tech., Chicago, Ill.

MEETING—San Francisco, Calif.

#### Transport Properties

CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Company, Baytown, Texas.

MEETING—San Francisco, Calif.

#### Applied Thermodynamics

CHAIRMAN: W. C. Edmister, Calif. Res. Corp., 576 Standard Ave., Richmond, Calif.

MEETING—San Francisco, Calif.

#### Fluid Mechanics

CHAIRMAN: R. W. Moulton, Head, Dept. Chem. Eng., Univ. of Washington, Seattle, Wash.

MEETING—San Francisco, Calif.

#### Distillation

CHAIRMAN: D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

MEETING—St. Louis, Mo.

#### Dust and Mist Collection

CHAIRMAN: C. E. Lapple, Dept. of Chem. Eng., Ohio State University, Columbus 10, Ohio.

MEETING—St. Louis, Mo.

#### Drying

CHAIRMAN: L. E. Stout, Dept. of Chem. Eng., Washington Univ., St. Louis 5, Mo.

MEETING—St. Louis, Mo.

#### Use of Computers in Chemical Engineering

CHAIRMAN: John R. Bowman, Head, Dept. of Res. in Phys. Chem., Mellon Institute of

Authors wishing to present papers at a scheduled meeting of the A.I.Ch.E. should first query the Chairman of the A.I.Ch.E. Program Committee, Loren P. Scoville, with a carbon copy of the letter to the Technical Program Chairman of the meeting at which the author wishes to present the paper. Another carbon should go to the Editor, F. J. Van Antwerpen, 120 East 41st Street, New York 17, N. Y. If the paper is suitable for a symposium, a carbon of the letter should go to the Chairman of the Symposia, instead of the Chairman of the Technical Program, since symposia are not scheduled for any meeting until they are complete and approved by the national Program Committee. Before authors begin their manuscripts they should obtain from the meeting Chairman a copy of the Guide to Authors, and a copy of the Guide to Speakers. The first book covers the preparation of manuscripts, and the second covers the proper presentation of papers at A.I.Ch.E. meetings. Presentations of papers are judged at every meeting and an award is made to the speaker who delivers his paper in the best manner. Winners are announced in *Chemical Engineering Progress*, and a scroll is presented to the winning author at a meeting of his local section. Since five copies of the manuscript must be prepared, one should be sent to the Chairman of the symposium and one to the Technical Program Chairman of the meeting, or two to the Technical Program Chairman if no symposium is involved and the other three copies should be sent to the Editor's office. Manuscripts not received 120 days before a meeting cannot be considered.

## PEOPLE

The appointment, effective April 15, of DeWitt O. Myatt to the newly created position of



manager of development of the Atlantic Research Corp., Alexandria, Va., was recently announced. Mr. Myatt will co-ordinate the industrial research and development, marketing, and contract research programs of the company.

Mr. Myatt joins Atlantic Research after seven years of service with the A.C.S. as managing editor of Industrial and Engineering Chemistry. Prior to that, he was with the Tennessee Valley Authority, engaged in chemical engineering process development, technical report editing, etc. Mr. Myatt received the bachelor's and master's degrees in chemical engineering from the University of Louisville. Mr. Myatt has served on A.I.Ch.E. committees, such as the Professional Guidance and the Symbols and Nomenclature.

Clifford Armstrong has been appointed exclusive agent for the Carboline Co. covering sections of Michigan, Ohio, and Ontario. He was formerly a materials engineer with Wyandotte Chemicals Corp., Wyandotte, Mich.

### PROFESSOR HOUGEN TO LECTURE IN GERMANY

Olaf A. Hougen, chairman of the chemical engineering department, University of Wisconsin, Madison, is now in Germany for a period of two weeks in the interest of chemical engineering education. Professor Hougen will deliver a lecture before the Bunsen Physical Chemistry Society in Duisberg.



Professor Hougen has been associated with the University of Wisconsin for thirty years. He is at present chairman of the Institute's Award Committee, and in the past has served on the Nomenclature Committee and as chairman of the Projects Committee. In 1944, Dr. Hougen received the Walker Award and in 1950 he delivered the Second Annual Institute Lecture on Reaction Kinetics which was subsequently published as the "C.E.P." Monograph Series No. 1.

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Osborne Bezanson, president of The Chemstrand Corp. since 1950, has been elevated to the chairman of the board, effective Dec. 1. Prior to being president of Chemstrand, he was a vice-president and director of Monsanto Chemical Co., which with American Viscose Corp. jointly owns Chem-



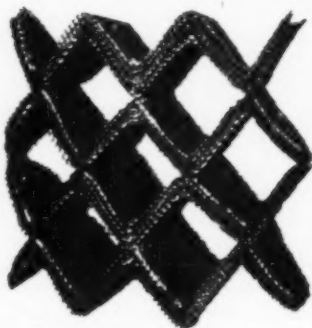
strand as an associate company. His last post with Monsanto was as a member of that firm's executive committee. He began his professional career in 1906 as a laboratory assistant for the Merrimac Chemical Co., Woburn, Mass. Four years later he was made chief chemist and later entered the operating and production phases of the company. In 1920 he was appointed assistant to the president. The following year he was appointed works manager and in 1927 was promoted to production manager of the Merrimac Co. Henry H. Bitler succeeds Bezanson on Dec. 1. Mr. Bitler has been with American Viscose for thirty-three years, serving in many capacities, such as general manager of the acetate and Vinyon manufacturing. After graduation from Swarthmore College in 1920 with a chemical engineering degree, he was employed as a laboratory technician at the Marcus Hook plant of American Viscose. He served as assistant superintendent in that location and in the same capacity at the Lewistown, Pa., plant. After a service period as manager of the Meadville plant, he transferred to the corporation's headquarters at Wilmington, Del., as assistant technical director.

### McNAMEE RECEIVES 1953 HERTY MEDAL

Raymond W. McNamee, superintendent of the research and development department, Carbide and Carbon Chemicals Co., South Charleston, W. Va., has been chosen by the American Chemical Society's Georgia Section to receive the 1953 Herty Medal. Dr. McNamee, the twenty-first Herty medalist, received his Ph.D. (1933) from Northwestern University. He joined the South Charleston Research Laboratories of Carbide and Carbon Chemicals Co. in 1933. During World War II, he assisted in the development of a process for the manufacture of styrene, one of the basic raw materials for synthetic rubber. In addition, Dr. McNamee has assisted Union Carbide and Carbon Corp. in the establishment of a program of university fellowships in physical and organic chemistry.



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**E. T. Powers**, who has been associated with the administration of the chemical division of the Celanese Corporation of America since 1945, has been promoted to the new position of director of the development department. The new department was established to appraise all technological advances here and abroad which affect the varied manufacturing and research activities of the company. The unit will coordinate technical programs of both domestic divisions and foreign affiliates.

The appointment of **Wallace P. Dunlap, Jr.**, as production superintendent of Monsanto Chemical Co.'s Soda Springs, Idaho, plant was recently announced. He had been serving as maintenance superintendent at Soda Springs for the past six months. Graduated from Massachusetts Institute of Technology in 1947 with a B.S. degree in chemical engineering, he was first employed by Monsanto at Trenton in March, 1947, as a chemical engineer. In March, 1952, he was named supervisor of the new chlorine plant at Anniston.

**Robert F. Meehan** is now in the development department of Monsanto Chemical Co.'s phosphate division, St. Louis, Mo., engaged in commercial exploitation of new products and market analyses for that division. After receiving a B.S. degree in chemical engineering from Rensselaer Polytechnic Institute, Meehan joined Monsanto as a research chemist in 1943. Since 1947, he has been a section chief in the operations division at Mound Laboratory, the Atomic Energy Commission installation operated by Monsanto at Miamisburg, Ohio.

**A. Monsaroff** was recently elected to the board of directors of Barringham Rubber & Plastics Limited. Mr. Monsaroff is vice-president of Monsanto Canada Limited.

**John W. Shier** has recently been appointed production manager at the

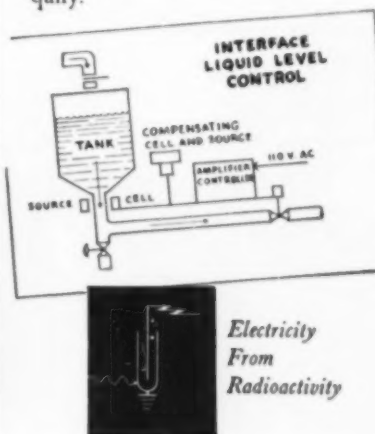
Acheson Colloids Co., Port Huron, Mich. He went to Acheson in 1949 as plant engineer. Before joining the Acheson organization, Mr. Shier was employed as a chemical engineer by the Heyden Chemical Co., Detroit, Mich. He attended the University of Michigan and was graduated as a chemical engineer from Wayne University. The Acheson Colloids Co., division of Acheson Industries, Inc., manufactures colloidal graphite dispersions.



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Clifford L. Sayre, veteran of two wars, has returned to civilian life after



eighteen months' active duty at headquarters for chemical research and development, Army Chemical Center, Maryland. Colonel Sayre will return to his position as development chemical engineer with the Buffalo Electro Chemical Co. During World War II Colonel Sayre served in the office of the chief of Chemical Warfare Service where he was executive officer of the Materiel Command. An alumnus of Carnegie Tech and University of Buffalo, Colonel Sayre majored in chemical and mechanical engineering.

Charles C. King, who has been associated with the M. W. Kellogg process department for fourteen years, has been placed in charge of the new special division just established to be devoted exclusively to the process design of plants for the petrochemical and chemical fields. Mr. King will be responsible for Kellogg's present and future work on such processes as those for the production of olefins, higher alcohols, aromatics, etc.

George B. Allen, former sales manager of the chemical equipment division, General Ceramics and Steatite Corp., Keasbey, N. J. has recently formed his own company, Allen Engineering Co., located in Cranford, N. J. It will handle, among other assignments, the General Ceramics lines of porcelain, stoneware and plastic equipment in the New York, North Jersey and New England areas. Before joining the General Ceramics Co., Mr. Allen was with the Haveg Corporation of Newark, Delaware and DuPont Co., Wilmington.

Warren P. Goss has been appointed mix processing engineer of the Pillsbury Mills, Inc. Mr. Goss, who holds a degree of chemistry engineering, has had long experience in research and engineering fields. He joined Pillsbury in 1946, after working in research laboratories of the U. S. Department of Agriculture, and has worked as associate director of research for Pillsbury since.

D. S. Alcorn, with Carbide and Carbon Chemicals Co. since 1943, has been transferred to the New York offices to assist with the market development of chemicals being produced at the new coal-hydrogenation plant at Institute, West Va.

## E. V. MURPHREE HONORED

Eger V. Murphree, president, Standard Oil Development Co., has been presented with the Industrial Research Institute's 1953 Medal. In accepting, Dr. Murphree gave an address titled "Our Most Important Form of Energy." He was the winner of the Perkin Medal for 1950.

Leo E. Ryan, executive vice-president of Monsanto Canada Limited, is now responsible for all the operations of the company. He has been associated with the company since manufacturing activities were started in Canada. He became vice-president and director in 1945, and was named executive vice-president in 1949.

C. P. Cunningham was recently made production superintendent of Monsanto Chemical Co.'s Trenton, Mich., plant. He was first employed by Monsanto at its division research laboratory in Anniston, Ala., and later transferred to the Trenton plant, becoming production supervisor in April, 1952. He received his B.S. degree in chemistry in 1944 from the University of Alabama.

## J. B. WIESEL RETIRES

J. Boiseau Wiesel, assistant to the general manager of Hercules Powder Co.'s cellulose products department, retired April 30 upon completion of thirty-seven years with the company. He received both an A.B. and M.A. degree from the Loyola College of Baltimore, Md., and pursued his post-graduate studies in chemistry and physics at Johns Hopkins University for three years. Mr. Wiesel taught chemistry in Baltimore from 1912 to 1915, and then joined Hercules as a chemist at a plant in Curtis Bay, Md., which was operated jointly by Hercules and U. S. Industrial Alcohol Co. to produce acetone needed in the manufacture of explosives for World War I.

Subsequently, Mr. Wiesel served at the Hercules plant at Parlin, N. J., and the Wilmington offices. In 1930 he was named director of sales for the cellulose products department, later becoming adviser to the chief of protective and technical coating section of the War Production Board. Subsequently he was named assistant to the general manager of the cellulose products department.

Louis F. Loutrel, Jr. has been appointed manager of sales development of Maumee Development Co., Toledo, Ohio. He will handle sales development of new products in addition to saccharin, anthranilic acid, dithiosalic acid, and phthalimide now being produced. He was formerly assistant to the general manager, Merrimac division of Monsanto Chemical Co.

Harold T. J. Littleton and W. Henry Linton, Jr., have been promoted from chemical engineers to research supervisors in the research division of the Du Pont Co.'s polychemicals department at the experimental station in Wilmington, Del. In his new post, Mr. Littleton supervises engineering development of various new processes, with emphasis on plant design. During his career with the company he has helped develop processes for making nylon intermediates and in 1949 helped put the Orange, Tex., nylon plant into operation. He received his bachelor's degree in chemical engineering from the University of Virginia, and for three years following graduation he served at the Naval Research Laboratory, Washington, D. C. He joined Du Pont in 1949.

Dr. Linton will direct chemical and physical studies of polymer structures. He joined the company in 1949, at the Arlington, N. J., plastics plant, and a year later was transferred to the experimental station in Wilmington. He worked on the development of processes for making chemical intermediates, nylon intermediates, etc., and process cost studies. He received his degree of doctor of science from Massachusetts Institute of Technology, where he majored in chemical engineering.

P. John Clarke has joined the staff of the research division of the Standard Oil Development Co., Linden, N. J., after three years' service with the Humble Oil and Refining Co. Mr. Clarke received both his bachelor's and master's degrees in chemical engineering from the University of Michigan. During World War II, he served more than three years with the Army Air Forces.

Paul Ferencz, formerly senior chemical engineer with Canadian Industries, Ltd., is now engaged in private consulting work, specializing in problems of design, development and applied statistics. Before joining Canadian Industries, Ltd., Dr. Ferencz, a graduate of the technical universities of Budapest, Hungary (1910), and Karlsruhe, Germany (1912), worked with the I. G. Farbenindustrie and other companies in Europe as plant superintendent and manager.



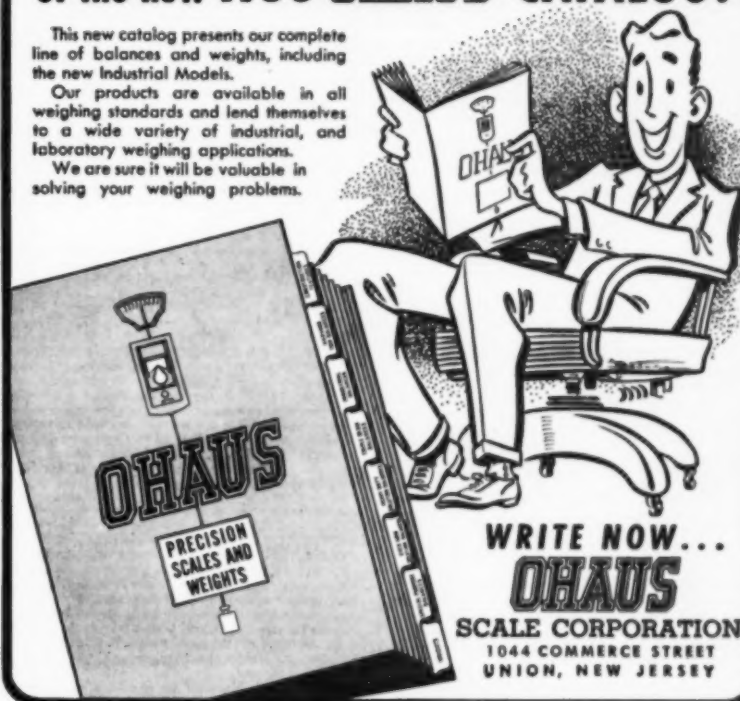
Gustav Egloff, director of research of Universal Oil Products Company, has been elected second vice-president of the Chicago Post of the Society of American Military Engineers, for 1953. (More About People and Necrology on page 76)

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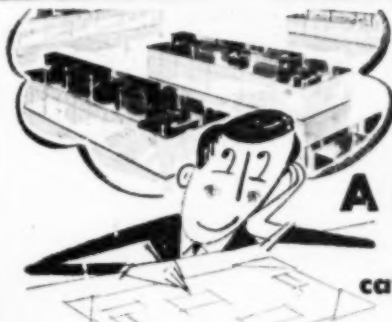


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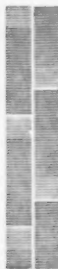
**CHEMICAL ENGINEER**—Instructorship open in Paper Engineering Department of Eastern school. Teach chemical engineering subjects and supervise mill practice course. Opportunity to obtain advanced degree in Paper Engineering. Box 31-5.

**WANTED FOR EMPLOYMENT IN MEXICO**—Chief engineer for Frasch process sulphur recovery plant. Must be thoroughly conversant with water tube boilers, high pressure air compressors, turbo alternators, and hot process water softeners. Good salary and contract to suitable applicant. Reply giving fullest details past experience. Men with foreign experience and who speak Spanish preferred. Box 5-5.

**CHEMICAL ENGINEER, CHEMIST OR BIO-CHEMIST**—To take charge of small program of research on sewage treatment methods at Queen's University, Kingston, Ontario. Program requires the full time employment of person capable to undertake and to direct pilot plant studies on purification of industrial waste. Salary open. Further details on request.



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In reply state technical background and experience. Reply to Department No. 3500, Box No. 6-5.



## SITUATIONS WANTED

### A.I.Ch.E. Members

**ENGINEERING MANAGER AVAILABLE**—Chemical engineer with background in complete plant design and preparation and analysis of budgets for existing and proposed industrial installations. Bulk of previous experience in detergent, pharmaceutical, and organic chemicals fields. Metropolitan N. Y. preferred. Box 1-5.

**PATENTS**—B.S.Ch.E., LL.B. Awaiting results New York March Bar. Age 31. Five years' experience process and equipment design for petroleum, chemical, and ore beneficiation plants. Excellent writer. Seek position in patent field. Box 4-5.

**SUMMER EMPLOYMENT**—Young chemical engineering professor with excellent academic background including D.Sc. degree desires process design, pilot plant, research or any other industrial work. Alien in process of naturalization. Married. Good references. Box 7-5.

**CHEMICAL ENGINEER**—M.S. Age 29. 5½ years' development experience. Considerable knowledge of process design, report writing, and cost estimation. Excellent pilot plant background and some production experience. Minimum salary \$7,500. Box 8-5.

**CHEMICAL ENGINEER**—B.S.Ch.E. 28, married, veteran. Five years in petrochemicals and aircraft processing. Experienced in process control and technical service. Desire responsible position in petrochemical, petroleum, or heavy chemical industries. Prefer permanent location in Southwest area. Box 9-5.

**REGISTERED CHEMICAL ENGINEER**—B.Ch.E. M.S.(Ch.E.) and courses in industrial engineering. Two years' industrial experience. Five years teaching chemical engineering and directing sponsored research. Desire position with opportunity for advancement in metropolitan area of Gulf Coast states. Box 10-5.

**FOR SALE EXECUTIVE TALENT**—A good investment worth investigating. Chemical engineer eleven years' experience design, sales, and administration desires permanent responsible position preferably in Southeast. Age 33. Your inquiry will be acknowledged promptly. Box 11-5.

**CHEMICAL ENGINEER**—B.Ch.E. 1951. Veteran. Age 24. Experience in production supervision, handling production problems and trouble shooting. Desire position with small progressive company. Present salary \$85. Box 12-5.

**CHEMICAL ENGINEERING COORDINATOR**—B.Ch.E. R.P.I. 34. With ten-year mechanical-chemical background in operating, staff and project design engineering desires to join small California growth-minded chemical, plastic or equipment company. Proven results obtained with large chemical company in developing, selling and applying improved manufacturing and engineering equipment and techniques for increased profitability. Box 13-5.

**CHEMICAL ENGINEER**—B.S. 1950. Three years' experience in process design and process engineering. Desire position with a future in design and/or development. Location immaterial. Veteran with family. Box 14-5.

**CHEMICAL ENGINEER**—M.S.Ch.E. 1949 Columbia University, European degree in industrial chemistry, languages. Three years' experience as assistant to technical director in coating industry. Age 31, family, American citizen. Would like challenging opportunity for career. Location secondary. Box 15-5.

**CHEMICAL ENGINEER**—B.S. in Ch.E. Age 28, family. Five years' experience heavy chemical industry in operation, design and development. Desire position as production supervisor or technical service representative with chemical manufacturing organization. Box 16-5.

**INDIAN**—Associate member. Apprenticed in United Kingdom. Seven years in erection, start-up, and production supervision. Mostly in fertilizers and acids. Willing to enter other lines. Prefer assignment in India. Box 17-5.

**ADMINISTRATIVE CHEMICAL ENGINEER**—Registered professional engineer. Age 37. Experienced production, plant, general superintendent, production manager. Fifteen years' chemical plant administrative experience in alcohol, whiskey, rayon-cellophane, fertilizer, sulfuric acid, soybean oil solvent extraction, submerged fermentations, commercial yeast, riboflavin, Vitamin B-12. Also interested other fields. Very adaptable. Box 18-5.

**CHEMICAL ENGINEER**—Ph.D. in Fall 1953. Desire process development or technical service to production—small or large company. Prefer New England location. Three years' experience in production and development (economic studies) prior to graduate study. Box 19-5.

**M.S.Ch.E.**—Thirteen years construction engineering, process development, equipment design, selection, evaluation, economic studies. Presently chief process engineer medium sized department doing high volume, broad scope design. Q-cleared. Active A.I.Ch.E. Salary \$10,000. Prefer Midwest. Box 20-5.

**TECHNICAL SALES-MARKET DEVELOPMENT COORDINATION**—Ch.E., 29, business training. Unusually diversified domestic-foreign experience at administrative level in major companies. Strong supervisory record. Ability, character and personality above average. Need growing responsibilities in medium size organization. Box 21-5.

**TECHNICAL ADMINISTRATOR**—Licensed chemical engineer. Fifteen years' diversified experience in protective coating and food fields. History includes organization and administration of both production plants and research laboratories. West Coast location preferred. Age 38, family, veteran. Box 22-5.

**CANADIAN ENGINEER**—Fourteen years' experience petroleum and related chemicals. Responsible charge plant construction and process design. Sound background cost estimating, process evaluation, research planning. Salary \$10,000. Desire join small firm Pacific Coast or Canada. Box 23-5.

**CHEMICAL ENGINEER**—M.S.Ch.E. 28. Five years' diversified experience development, production, and plant management. As assistant to plant manager in new million-dollar company, built plant from idea stage to successful operation. Capable of unusual responsibility. Box 24-5.

**CHEMICAL ENGINEER**—Registered professional engineer with extensive experience in coal chemicals, synthetic fuels, organic chemicals, process, plant and equipment design. Supervisory and administrative experience. Desire industrial connection. Box 25-5.

**CHEMICAL ENGINEER**—M.S. 1947. Three years' experience evaluating petroleum refining processes, including process design and cost estimation. Additional year graduate work in thermodynamics, kinetics and unit operations. Three years' earlier pilot plant experience. Tau Beta Pi. Desire responsible position in process design or process evaluation. New York City area desired. Box 26-5.

**CHEMICAL ENGINEER**—M.S. Age 34. Eight years' research experience in plastics and resins processing. Proven initiative and imagination. Veteran. Present salary \$7,000. Box 27-5.

**CHEMICAL ENGINEER**—Fourteen years' progressive experience in process design, evaluation and development; process equipment design and sales engineering. Advanced degrees. Publications. Age 39. Desire responsible position with opportunity for advancement. Box 28-5.

**CHEMICAL ENGINEER**—Sc.D. Capable excellent performance research, process and product development. Desire position with company expanding facilities. Fifty-mile radius Boston. Four years industry, six years teaching—research. Available July. Box 29-5.

**SENIOR CHEMICAL ENGINEER**—M.S.Ch.E. Twelve years' experience process design, development, and supervision both inorganic and organic. Specialties include spray drying. Top scholastic record, honor societies, publications. Age 33, family. Box 30-5.

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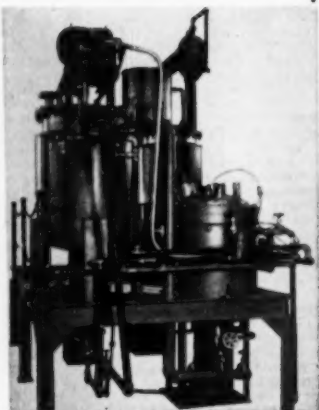
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## PEOPLE

(Continued from page 73)

The appointment of **F. R. Keller** as assistant chief plant engineer at American Cyanamid Co.'s plant now under construction near New Orleans, La., was recently announced. A graduate of Syracuse University in 1939 with a B.Ch.E., Mr. Keller joined Cyanamid in 1943. He has served with the company's industrial chemicals division, engineering department, and most recently the atomic energy division's Idaho Falls, Idaho, plant where he was assistant to the plant manager.

**A. W. Davison** has just recently resigned as director of research, Owens-Corning Fiberglas Corp., Newark, Ohio. He will set up a consulting office in chemical engineering and technical personnel management in Newark, Ohio.

**Nat Kessler** has recently been made a senior chemical engineer at the A. E. Staley Manufacturing Co., corn and soybean processor. Kessler had been technical superintendent of the Staley company's soybean solvent extraction plant at Painesville, Ohio, and will now have charge of chemical engineering in connection with the soybean extraction plants, etc., at Decatur, Ill.

## Necrology

Chemical Engineering Progress recently heard of the death of the following members of A.I.Ch.E.:

**J. P. Custis Peter**, 54, chemical engineer, Synthetic Rubber, Reconstruction Finance Corp., Washington, D. C. Mr. Peter had worked in the Government synthetic rubber program since 1943. Previously, he was employed by American Cyanamid Co. in New York City.

**P. Avard Smith, Jr.**, department head with Carbide & Carbon Chemicals Co., Houston, Tex. Becoming associated with Carbide in 1933, he served both in the control laboratory and the development laboratory, South Charleston, W. Va., and later went to Texas City, Tex.

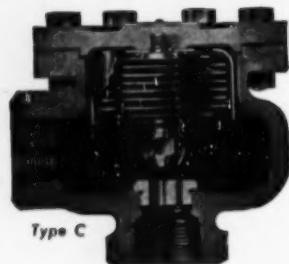
**Raymond J. Lakey**, vice-president and chief engineer, Shea Chemical Corp., Columbia, Tenn., and Baltimore, Md. In a similar capacity he had served Hoosac Valley Lime Co., Adams, Mass.

**George W. Smith**, assistant to director of research, Pittsburgh Coke & Chemical Co. Mr. Smith had a long professional career, being associated with the Aetna Chemical Co., American Cyanamid Co., and as an instructor of mathematics with the Carnegie Institute of Technology.

## Nicholson Steam Traps

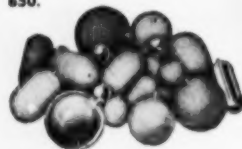
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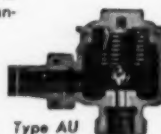


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Jackson Blvd., Room 800, Webster 9-2225.

Cleveland 15—Douglas H. Boynton, Dist. Mgr.,  
1836 Euclid Ave., Superior 1-3315.

Pasadena 1—Richard P. McKey, Dist. Mgr., 465  
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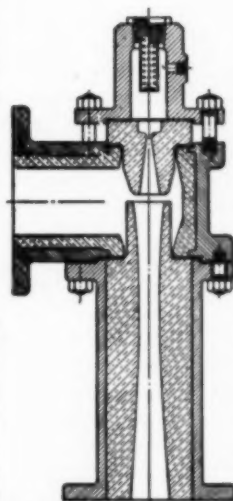
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## THE PRESIDENT SAYS



A big part of the good done by A.I.Ch.E. is the result of volunteer effort by its members.

A big part of the good done by A.I.Ch.E. is the result of volunteer effort by its members. Committee work accounts for much of the result, and much comes from section activities all over the country. If we had to pay all the people who work for the Institute, we could not afford it. Letters I am getting from interested members and conversations I have as I travel, indicate occasional impatience with the rate at which Institute affairs move. One example has to do with our publications. Several people say they would like to see us add a publication quite like the Transactions which CHEMICAL ENGINEERING PROGRESS replaced in 1947. They believe that the more highly technical material should be printed in a Transactions and those most interested could subscribe separately. Others believe that Symposium Series and Monographs, such as we now issue on separate subscription, best answer our needs. There is much to be said for these viewpoints and it is being said on many occasions.

Because Council recognizes the importance of publication activities, we have made changes in the applicable committee setup. Whereas, formerly, the Publication Board of "C.E.P." has been identical with the Executive Committee of Council, virtually ex-officio, we now have an entirely separate group under the chairmanship of our able Vice-President, Chalmers Kirkbride. He has put together a group with the idea in mind that members of the Publication Board should be chosen for business acumen and background in Institute publication affairs.

A further move is to strengthen the Publication Committee (which is separate from The Publication Board). This committee concerns itself with policy matters. In recent years, the Vice-President of the Institute has been chairman ex-officio. Current thinking in Council is against such an automatic appointment. We believe we shall get fresher viewpoints and more work from someone not already deeply involved in Council enterprises. Tom Sherwood of M.I.T. is our new chairman and has formed a group of active-minded, sincere members who are already tackling current problems.

These are examples of Council thinking which I hope you will like. We are visualizing more people in im-

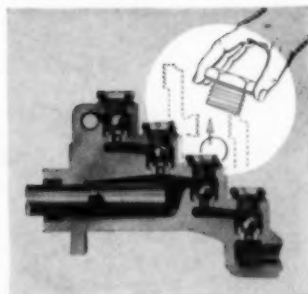
portant roles in Institute affairs and trying to avoid the error of concentrating too much responsibility in the hands of too few people. The truth is that our membership roster is jam-packed with capable people, many of whom would like to take on vital jobs. Council's problem is to tap this resource and to develop new techniques. For example, to get around the difficulties which retard accomplishment when members of a committee are geographically scattered, we are singling out an able individual who will form a committee of members in fairly close proximity to accomplish some specific objective. A recent case of this sort was the assignment of Arthur Doolittle, by Council, to study matters pertaining to membership grades and requirements. Art picked out a couple of members who are employed near him. They were able to organize promptly and shortly met with a group of members of the Charleston Section to debate several questions. The result has been that, although this assignment was made on January 16, at our first Council meeting of the year, Doolittle's committee reported at our March Council meeting at Biloxi. All three members attended the Council session, incidentally, so we received a first-hand detailed report.

Since all this committee work is on a volunteer basis, we cannot always get along as fast as desired. We must not demand too much from men who are faced with the necessity of giving their first consideration to earning their livelihood. Occasionally one of our important committee chairmen runs into difficulties, and, of course, the sensible thing for him to do is to ask for help, delegate responsibility to others or, if the situation warrants, resign. Council is encouraging chairmen to use competent vice-chairmen to guard against such circumstances, and the officers would be glad to see greater use of younger members.

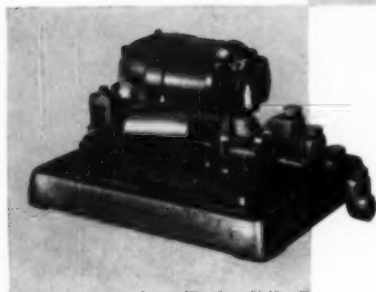
The time is near, I feel sure, when certain activities now handled on the volunteer basis will have to be handled by paid personnel. I hope to have more to say on this subject later this year.

*W. J. Nichols*





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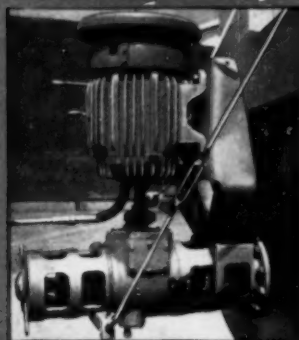
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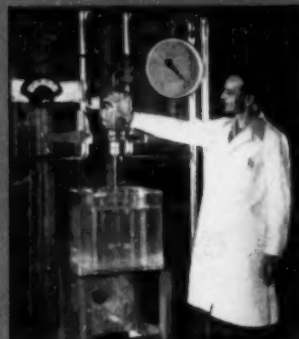
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- ☐ B-103 Top Entering Mixers (propeller type)
- ☐ B-104 Side Entering Mixers
- ☐ B-105 Condensed Catalog (complete line)
- ☐ B-107 Mixing Data Sheet

Please send me the catalogs checked at left.

Name \_\_\_\_\_ Title \_\_\_\_\_

Company \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_